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A KINEMATIC AND ELECTROMYOGRAPHIC ANALYSIS OF THE RUGBY PUNT USING THE PREFERRED AND NON PREFERRED FOOT

by

© ANTHONY BAUER

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

FALL, 1981

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled A Kinematic and Electromyographic Analysis of the Rugby Punt Using the Preferred and Non Preferred Foot. submitted by Anthony Bauer in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY

DEDICATION

In dedication to both my mother and father for their support and preseverance during my early life and education.

ABSTRACT

The purpose of this study was to investigate and measure the kinematic and electromyographic parameters of the rugby punt when performed for maximum distance using the preferred and the non preferred kicking foot. Two dimensional high speed cinematography synchronized with electromyographic recordings of the lower extremity musculature was used for the testing procedure. The film was analyzed to give kinematic data including angular segmental accelerations, linear segmental accelerations, ranges of joint motion and the velocities of the centres of mass for six elite subjects performing the rugby punt with both the preferred and non preferred foot. Electromyographic recordings were recorded simultaneously for the Rectus Femoris, Biceps Femoris and the Tibialis Anterior of the kicking leg. Two subjects were chosen for a detailed analysis of a comparison between preferred and non preferred kicking. Results indicated inferior performance for the non preferred foot of all subjects. The kinematic parameters demonstrated a related lack of co-ordinated sequencing of limb segments. Electromyographical records indicated a close relationship between changing velocity levels and the percentage of maximum EMG levels in the lower limb segments.

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CHAPTER I

STATEMENT OF THE PROBLEM

INTRODUCTION

The skill of kicking in football involves angularly accelerated motion of the lower body limb segments. The motion reaches a point where the distal foot segment strikes the ball and propels it in the direction of the resultant forces acting at impact. There are numerous variations of the kick each of which depends on the specific type of football, the type of ball and the game situation.

The game of rugby developed distinctive characteristics when it was distinguished from Association Football (soccer) in 1863 in England where it was first refined and developed at Rugby School, then at Oxford, Cambridge, Richmond and Blackheath clubs. The distinguishing development was the provision for carrying the ball in the hands to attempt to gain forward progress. A progression from this point was the kicking of the ball from the hands. In 1823 British settlers and members of the Royal Navy introduced the game to Canada and in 1864 the first official Canadian Rugby rules were formulated at Trinity College in Toronto. The popularity of the game fluctuated considerably over the next 100 years and has experienced a major revival over the last thirty years.

The game of rugby involves the player in a variety of kicking situations, many of which involve the added complications of body contact. It is to the player's advantage to be able to kick accurately

and for distance using either the preferred or non preferred foot.

Rugby playing standards fluctuate considerably throughout the ten provinces of Canada with the greater majority of players in the game involved in a variety of other Canadian team ball games. Many of these games are played and developed within the school and community at all ages and levels. Rugby has not been developed in the same manner as have many of the more traditional games. There is however a strong tendency for involvement at a later stage in the individual's athletic career.

The coaching and teaching of the basic mechanical motions of the rugby punt is significantly lacking both at a club, provincial, national and even at the international level. The other basic skills of the game include running, tackling and passing. A player who is capable of performing accurate and effective distance punts using both the preferred and non preferred foot possesses a useful and quite often devastating skill when used at the correct strategic moment of a game. However, kicking is not effectively coached as a priority skill, a fact which contributes to a general lack in skill levels in developing provincial rugby.

A common characteristic in the consideration of skills involving a preferred side of the body is the reliance on that particular side. This reliance is based on initial learning processes at an elementary learning level. The motor learning patterns and motor pathways must be developed and enhanced at the earliest possible stage of the player's career (WICKSTROM, 1977; SINGER, 1966). With experience and time the player will reflexively move to either foot and complete the kick. Valuable time is lost and the accuracy of the kick is decreased

considerably, when a player maneuvers into a better position to use the preferred foot.

Research material relating to the rugby punt and kicking with the preferred and non preferred is non existent. The observations and discussions presented in the above paragraph are based on the writer's personal involvement while playing and coaching at the university and club level plus international playing experience over a number of years. Consequently, there is a great demand for extensive biomechanical analysis of rugby playing skills to enhance the coaching levels and playing standards of Canadian Rugby players.

To effectively analyze relatively high speed ballistic type movements a number of effective measuring tools have been developed. High speed 16 mm cinematography and electromyography has been used in combination with sophisticated digitizing computers, multi-channel amplifiers and recording devices. The nature of human ballistic motion is conducive to cinematographical and limb segment analysis (BEVAN, 1972; BRANDELL, 1968; GARRISON, 1965; GRAY, 1968; SPRIGINGS, 1977; VREELAND, 1977). Segmental analysis involves a quantitative measure of the body's trunk and limb segments as they vary their kinematic and kinetic characteristics. The skill of kicking involves the sequential motion of adjoining body segments so that the ultimate foot segment contact with the ball is maximized to provide the required distance and accuracy. The ballistic movements of both throwing and kicking require the individual limb segments to reach an optimum velocity so that maximum speed or striking force can be imparted onto the implement.

> "The proper timing of the accelerations and decelerations of each segment (with a range of motion sufficient to allow this timing) and a solid impact of the foot will produce maximum ball velocity." (PLAGENHOEFF, 1971, p. 102)

Analytical problems arise when a skill is inaccurately described and significant movement contributions are not considered. The throwing movement involves considerable rotation of the trunk and extremity segments around a longitudinal or vertical axis. A single plane analysis therefore will not consider movements in a frontal or transverse plane. The anatomical characteristics of the specific joints involved as well as the muscular attachments in relation to these joints will control movements in more than one plane. The motion of the lower extremity, during the kicking action of a rugby punt, is limited primarily to one plane. The angular motion of the thigh, lower leg and foot is in the sagittal plane (y) around a transverse frontal axis (x).

Additional information can be gained through a knowledge of the extent and co-ordinated timing of contracting musculature during a ballistic movement. Electromyography has been used effectively for many types of muscular movement analysis including gait patterns, running patterns and specific skill performances (ANGEL, 1975; Elliot, 1976; KAMON, 1966; DOMMASCH, 1972). The quantification of electromyographical results is an additional aid which can demonstrate the relationship between electrical muscle action potential levels and a variety of muscle contractile qualities. BOUISSET (1973) indicated a proportional relationship between integrated electromyography and muscle work. INMAN (1952) effectively indicated a parallel relationship between muscle tension and isometric contraction but demonstrated

no quantitative relationship between EMG and tension when the muscle is allowed to change its length. CLOSE (1960), however, using an electronic counter for muscle action potentials indicates a direct relationship between tension and both isometric and isotonic contraction.

There has been extensive investigation into the mechanics of relatively high speed ballistic movements (WELLS & LUTTGENS, 1976; KELLY, 1971; BROER, 1973; RASCHE & BURKE, 1974). In the present investigation the rugby punt will be analyzed when performed with the preferred and non preferred foot. A mechanical analysis of the lower limb segments will be combined with an electromyographical analysis of lower limb musculature. MACMILLAN (1976) relates the launch angle of the ball and the angular velocity at the knee to the flight of three different types of kicks in Australian rules football. ROBERTS (1974) compared vertical ground reaction forces calculated through both a force platform and film displacement measures while performing the soccer toe kick. ZERNICKE (1974) used the soccer toe kick for an analysis of the kinetic parameters of the lower limb and the contribution of selected limb segments to increments in resultant velocity. HOSHIKAWA (1974) examined the limb segment velocity contributions during throwing with the preferred and non preferred hand after fifteen weeks of training.

The present study will examine the rugby punt when performed by elite international rugby players. The kicking skill levels of all these players are considered to be the highest in Canada at the present time. Kicks of this calibre were chosen to represent as close to perfect model performances as possible so that skill performance

characteristics could be referred to developing kickers at lower skill levels.

THE PROBLEM

The purpose of the investigation was to determine the variation in selected kinematic and electromyographic changes which occurred during the rugby punt when performed by elite Canadian rugby players using both the preferred and non preferred foot.

The measurement techniques used included a segmental kinematic analysis of the trunk and lower limb segments of the kicking leg. The progressive acceleration and deceleration of limb segments were considered as variables for final foot velocity at impact with the ball. The sequential variation of these kinematic changes leading to impact velocity was measured and compared. The resultant limb segment motion was also examined through the muscular contractions initiating and promoting the motion. Electromyographic muscle potential recordings were used to determine the instant at which a particular muscle contracted, to either initiate and accelerate, or decelerate segmental motion.

STATEMENT OF THE PROBLEM

The purpose of the investigation was to determine the sequential patterning variations in selected kinematic and electromyographic variables which occurred during the rugby punt when performed by elite Canadian rugby players using both preferred and non preferred foot.

The following sub problems were identified:

1) the kinematic variations in the trunk and lower limb segment of the kicking leg.
2) the kinematic variation of each adjoining segment up to the point of impact.
3) the position and motion of the kicker's centre of mass.
4) the range of motion of the trunk, hip, knee and ankle.
5) electromyographical muscle action potentials of the Rectus Femoris, Biceps Femoris and the Tibialis Anterior.

DELIMITATIONS

The study was delimited to:

1. Six highly skilled Canadian rugby players, two of whom were chosen for comparative analysis.
2. Three trial kicks on each of the preferred and non preferred kicking feet.
3. A two dimensional sagittal plane analysis of the rugby punt for distance.
4. Electromyograms of the Rectus Femoris, Tibialis Anterior and Biceps Femoris.
5. Measurement of the rugby punt performed for distance.

LIMITATIONS

The study was limited by:

1. The reliability and accuracy of the measurement and recording equipment.
2. The consistency of the researcher in determing the anatomical segmental end points on film images.
3. The possible discomfort experienced by electrode implants during the motion of the kick.
4. Possible time lags during the recording of EMG from different muscle groups.

MEASUREMENT ERROR

The complexity, measurement methods and general nature of the study introduces errors which in some cases are adjusted for, but in other cases have to be considered constant.

The cinematographical analysis techniques introduce both operator and equipment error. The digitizing process relies upon the consistent location of segmental end points on film reproductions. Although the side of the body which is in consideration is in the camera view, body segments are often obscured and approximations are made. The foot segment in particular is difficult to distinguish at particular points during the kicking action. The photographic materials used for filming introduce film reproduction qualities which could not be controlled. Image qualities such as graininess, resolution, object size and blur were factors which caused difficulty when pinpointing specific points on the relevant segments. Frame rate inconsistency depends on the accuracy of the camera and calibration reliability. There are systematic errors which remain constant throughout the present study. Perspective error and distortion occur due to the camera and projector optics. The frame rate consistency is determined by the timing marks exposed on to the film through the Photosonics timing system. Correction factors are based on the accuracy of digitized points from a known object within the film frame. The programming and computation of the centre of mass is based on locating the segmental end points and using standardized anatomical input data. Percent body masses and data for the moments of inertia of each segment are derived from statistical analysis of a general population plus cadaver studies. The MIT scale is used as a source for this data, however it does not necessarily

reflect the true individual characteristics of each subject. Electromyographical output signals from the EMG amplifier units plus the 4-track FM tape recorder may be subject to unknown artifact sources. Contact of implanted wire electrodes, defective fine wire spring contacts and external artifact interference are possible error sources.

Error sources are minimized through a number of precautionary measures. Electromyographical output artifact is minimized through the use of heavily shielded light weight, four strand, lead wire which entirely restricts lead movement interference. Wire electrode implants are prepared to minimize the possibility of deinsulated wire tips coming into contact with one another. The procedures are outlined by (JOHSSON, 1968). A 60 cycle filtration system for each of the four amplifiers is utilized to reduce nearby electrical interference. Timing marks from the Photosonics timing system demonstrated high reliability in frame rates and recorded marks on the EMG readout. A large object of over three metres is used for an easily identifiable object for correction factor purposes. The perspective error is minimized by utilizing a maximum camera to subject distance. The Bendex Platen accuracy readings are given at $\pm$ .036 cm. Researcher error in taking consistent digitized points was measured by repeating all the input co-ordinates for the same subject five times. Raw data readouts for each of the five runs were surveyed to give a maximum error of $\pm$ 1.7 cm. The film frame rate of 100 f/s is measured through timing marks on the film to give a frame interval of .0105. Through pilot study trials, it was decided that 100 f/s provided ample image quality for the kicking motion.

CHAPTER II

REVIEW OF LITERATURE

Due to the limited research on the rugby punt and the ballistics relating to the skill this chapter will review related literature based on:

1) Analysis of kicking

2) Electromyography and Ballistic Motion

ANALYSIS OF KICKING

Intensive research analysis on the mechanical characteristics of kicking appear in a number of varied sources. The majority of studies relate primarily to kicking while the ball is in a stationary ground level position. The soccer drive or football place kick are the common examples and considerable similarities can be identified between these particular kicks and the rugby punt.

The soccer style kick and the place kick differ to the rugby punt primarily as a result of the ball position on impact with the foot. During the punt the ball is carried in the hands and must be positioned in the path of the foot. The movement involves co-ordinated transference of the ball onto the foot so that impact occurs at the correct moment during the accelerated motion of the foot segment. The point of impact between ball and foot for the punt and place kick occurs at different points along the angular path of foot motion. Similarities

between the punt and place kick appear specifically during the approach stage of the kick and the preparatory stages of angular acceleration of the kicking leg limb segments. PLAGENHOEF (1971) used a segmental analysis approach to compare different types of soccer kicks. One high skill level subject was used to perform both straight toe kicks and side approach kicks.

> "When analyzing kicking motions one must consider the pattern of the motion and the foot position at impact. Both will vary according to the position of the ball relative to the non kicking foot, available time, angle of approach, and the part of the foot being used for contact." PLAGENHOEF (1971:98)

Ball and foot velocities were compared and results indicated that ball velocity was not always proportional to foot velocity. Foot velocities were taken after impact and the striking mass was calculated. The conclusions were that foot placement on the ball is more of a variable than is foot velocity. Joint moments of force were measured at the hip and knee joints. The deceleration of the thigh was not consistent with the different types of kicks, however, kicks with the lowest thigh deceleration showed the greatest knee extension. The conclusion was, that the greater the muscle force used at one joint the lesser the force required in the adjoining segment to obtain an equal foot velocity.

Plagenhoef also demonstrated that foot contact was an important variable. When the subject performed the punt without wearing a boot, consistently longer kicks were the result. The "give" in the boot often reduced the striking mass of the foot and less distance resulted.

CARLSON (1977) compared two styles of punt kicking. The purpose of the analysis was to determine the mechanical differences between

the American three step and Australian five step punts. One skilled subject was filmed in the saggital plane using a Locam camera running at 500 frames per second. Dempster's segmental method and an X, Y co-ordinate system were combined with a Fortran computer to give centres of gravity (C of G), body segment accelerations and velocities in horizontal, vertical and linear directions. The path and velocity of the C of M were compared and indicated greater velocities with the Australian five step approach. Right hip horizontal velocities at heel plant and horizontal velocities at ball contact were greater in the five step approach. The linear velocities prior to and at ball contact were also greater with the longer approach. Angular velocities at both the hip and knee were considerably higher in the Australian punt and the launch velocities of the ball were proportionately higher.

The value of summation of horizontal forces to changes in the path of the C of G during the kicks plus the variations in force transference during the kicks were indicated through the longer approach to the punt. The range of movements in the hip and knee were proportional to the velocities generated in the limb segments. The greater the impact velocities, the greater the hyperextension and flexion of the hip and knee respectively. The effects of greater ranges in angular displacement were related to the shortening then sequential lengthening of the radius of gyration during hip flexion and knee extension. In the present study it was decided to standardize the approach to five steps.

The effects of varying the approach phase of the punt and the importance of the ball release from the hands is indicated by HAY (1973).

> "Although the punter imparts no forward velocity to the ball at the time he releases it, he simply lets it drop or guides it downward with his hands. The ball retains the forward velocity it had as a result of the kicker's forward motion." HAY (1973:268)

HAY (1973) used cinematography and manual calculations to compare an expert, an average and a novice punter in an American football punt situation. The conclusions were that there are basically five parameters which differentiate a good from a poor punter. The higher the skill level, the less the distance the ball dropped from the hands to the foot. The angle of trajectory was 47.5^{o} for the expert and for the novice 32^{o}. The time period to complete the kick from catch to impact was less for the expert (1.385 sec.) and greater for the novice (1.697 sec.).

MACMILLAN (1975) studied the determinants which affect the flight of the kicked football using three Australian rules punters as subjects. The determinants considered were the launch angle, the launch velocity, ball fit or the conforming of ball to foot shape and the aerodynamic characteristics of the ball. Multiple regression analysis was used to determine the relationship between the subjects' performance and the determining variables. MacMillan suggests that there are other variables which control launch angle and these were the difference between the long axis of the ball and the long axis of the foot plus the inclination of the foot to its path of travel. A Milliken DBM 5C camera fitted with a 50 mm lens was used for filming at a rate of 400 frames per second with an exposure time of 1/1200 of a second. The film was projected through a 40% Kodak Recordak P40 film reading system on to the platen of a Hewlett Packard 9810A Calculator which digitized the co-ordinates and transferred them into

a Hewlett Packard 28953 Paper Tape Punch.

The product moment correlation between launch angle and footpath angle was high and statistically significant. The indication was that footpath angle during contact was the major determinant of the launch angle of the ball. All three variables, launch, footpath angle and ball fit contributed to the prediction of launch angle. However, although the launch angle was predictable to some extent the behaviour of the ball during contact was not considered in the analysis. The conclusion that angular velocity at the knee is a major determinant of linear foot velocity was verified. MACMILLAN (1975) and DARLINGTON (1968) indicated considerable difficulties in the quantitative expression of predictor variables which in fact was the method used by MacMillan in his study. The general suggestions Macmillan offers is for further study into momentum transference from the foot to the ball.

ROBERTS (1974) compared the vertical ground reaction forces calculated from film displacement measures with vertical forces recorded by a force platform. The kicking motion was simulated in the form of a stationary movement where the supporting leg was stabilized during the swing. One experienced subject was used and the kick was filmed at 100 frames per second with a Milliken 15 mm pin registered camera fitted with a Comat lens. A force platform was linked with an Offner ink writer and a Hewlett Packard 9864A calculator. A digitizer recorded X and Y co-ordinates which were used by computer programs to calculate displacement of the centre of mass, limb velocities and accelerations. Kinetic analysis of joint moments were based on mass estimates from DEMPSTER (1955).

The vertical forces recorded by the force platform and the calculated vertical ground reaction force for the simulated kick indicated a direct relationship. The displacements and acceleration of the thigh and leg segments were graphed and indicated obvious variations due to the momentum transfer during deceleration and acceleration. Resultant moments at the hip, knee and ankle indicated a sequential relationship where peak angular accelerations reached their maximum after peak inertia of the preceding segment.

ZERNICKE (1974) also used the soccer toe kick to quantify kinetic parameters of the lower limb and measure the contributions of selected kicking limb segments. Five skilled soccer players performed three kicks resulting in low, medium, and high ball velocities. The ball velocity was measured by a Dark Field Velocimeter and the subjects were filmed with a Milliken 16 mm camera running at 300 FPS. Digitized co-ordinate points were transferred to computer cards and treated with four sequential Fortran programs. Component forces, resultant joint forces and moments of force of the kicking limb were computed. Ankle joint forces increased with increased limb velocity during the motion from full knee flexion to extension. Knee joint forces peaked twice, once because of maximum thigh angular acceleration and again at maximum positive knee angular acceleration. Hip joint forces varied according to the changes in angular accelerations and resulting changes in the anterior and superior force components at the hip. Resultant moments of force increased in proportion to velocities except for the hip where there was a slight retarding extensor torque just before contact.

Variations in the motor learning patterns of kicking have been observed through the use of cinematography. Characteristic motor learning

patterns of athletes learning a skill with the non preferred limb have particular application in the present study.

BLOOMFIELD (1979) analyzed the soccer kick with the purpose of categorizing fundamental motor patterns. Fifty six boys ranging from 2 to 12 years of age kicked a soccer ball four metres toward a target. A cinematographical analysis produced data which categorized subjects into one of six performance groups based on data from a mature, highly skilled subject, PLAGENHOEF (1971). Two cameras were used, a Photosonics 16 mm high speed camera running at 100 frames per second and a Bolex 16 mm running at 64 frames per second. The cameras were operated in two planes at 90^{o} to each other and produced both a lateral and anterior image. The results indicated a developmental trend in kicking. Characteristic movement variations were based on the degree of arm co-ordination, backswing, follow through, and the number of approach steps taken. Bloomfield indicated considerable skill variation within each group and suggested that in some instances children may not have to go through the more traditional stages of skill development. A particular individual may, in fact, omit early developmental stages. WICKSTROM (1977) however, suggests a fundamental learning pattern which progresses through organized stages. It is possible that these learning patterns will be similar to those of a mature athlete attempting to punt a football with his non preferred foot.

> "The punt is a difficult form of kicking for the child because it entails a complex co-ordination of body movements. He must move his body forward, drop the ball accurately, and then kick it before it touches the ground." WICKSTROM (1977:185-186)

The gradual refinement of these primitive learning patterns should logically occur when using either foot. The related literature dealing with skill analysis of preferred and non preferred limb motion is lacking, particularly for the lower extremity. Literature based on kicking with the non preferred foot appears to be non existent.

HOSHIKAWA (1974) studied the contribution of body segments to ball velocity during throwing with the non preferred hand. Four adults using both hands threw with maximum effort using four different throwing methods. The methods ranged from a normal throw which was then limited by no movement by the hip or trunk, and no use of the upper arm. The movements were filmed with a Bolex camera at 64 frames per second and the film data was reduced using a Graf-Pen system. EMG's of bilateral musculature were taken from both upper and lower extremities using bipolar surface electrodes. Each subject then trained with the non preferred hand for 15 weeks, three times a week throwing 50 times during each training session. Results indicated greater ball velocities when more segments of the body were brought into action. The differences between preferred and non preferred hands were progressively greater as more limb segments were used in the motion. The ball velocities increased in the non preferred hand after the training period and the differences between the two sides decreased. The contribution of the peripheral segments, shoulder and elbow, to the velocity of the throw is relatively greater for the non preferred hand. Even after training, the contribution of the peripheral segments was still greater in the non preferred hand.

When the three types of throws were compared, the differences in segment contributions were less in the distal segments of the shoulder,

elbow and wrist. This finding was of special interest as the distal segments were considered to be the major contributors to ball velocity. The sequencing and timing of segmental actions in both preferred and non preferred throws before and after training are indicated. The slower and more powerful levers, the hip and trunk, begin their forward movement prior to action in the faster but relatively weaker elbow and wrist segments. A possible limitation to this study was the failure to consider rotation velocities and accelerations around a vertical axis. Three dimensional photography and analysis would porribly indicate significant contributions of the trunk and hip segments during the throw.

Hoshikawa does not effectively relate the EMG recordings to the kinematic characteristics of the throw. The muscle action potentials of the non preferred hand were recorded while throwing with the preferred hand. The level of EMG activity was stronger on the non preferred side than it was when the non preferred arm was actually throwing. An explanation or discussion of this finding is not given.

The resulting increases in ball velocity after training were suggested as a confirmation of improved neuromuscular co-ordination without radical hypertrophy of the muscle. The non preferred throw indicated a 40% contribution to ball velocity from the step and trunk movements while the preferred throw indicated a 50% contribution. The action of the distal segments in the non preferred throw was more significant than in the preferred throw.

ELECTROMYOGRAPHY AND BALLISTIC MOTION

As a consequence of intensive developments in electronic techniques electromyography (EMG) has taken on a new dimension in both clinical and kinesiological fields. The studies considered in this review will deal with the concepts of muscular activity and ballistic movements. The use of EMG to indicate the contraction of a particular muscle group during a limb movement is readily accepted by researchers. However, to effectively quantify EMG and relate the levels of electrical activity to the many physiological and kinematic parameters of muscular contraction is a more formidable task. Through the use of a wide variety of testing instruments, testing procedures and analysis techniques the EMG researcher has presented varied and often conflicting results.

In this study, the researcher is concerned only with the ballistic movement of kicking. KELLY (1971) defines a ballistic movement as follows:

> "When a muscle contracts with great force over a short increment of time, the force, as we have seen, may be considered an impulsive force. The torque of the force, which is responsible for the rotation of the body segment, is then called an impulsive torque. If the muscle contraction is terminated after a period of time, the segments' momentum will support continued rotation without additional muscle action. This type of movement is know as ballistic movement and it will persist until some counterforce is applied in opposition." KELLY (1971:135)

EMG indicates when a muscle contracts; it is somewhat more difficult to determine to what degree muscle maintains or increases its contractile quality when the limb segment is moving at a high velocity. Kelly states "the segments' momentum will support continued rotation without additional muscle action". One of the purposes of

this study is to demonstrate the variations in the EMG levels of three major muscle groups controlling the lower limb segments in the rugby punt. It is questionable whether or not the muscle continues to contract in proportion to the accelerating limb segment. Gait related studies indicate that the hip does flex when the rectus femoris contracts and that the knee does extend on the contraction of the vastus muscles. DOMMASCH (1972), JACKSON (1972). However, these are relatively low velocity non ballistic movements involving a greater degree of neuromuscular control. Few studies have effectively related variations in EMG activity to the velocity of the limb segment and the shortening musculature initiating the motion.

GOTO (1976) used three male adult subjects pedaling a bicycle ergometer to relate integrated EMG levels to load, frequency, power and oxygen consumption changes during exercise. Surface electrodes recorded integrated EMG for 10 seconds from the vastus lateralis, gastrocnemius and tibialis anterior muscles. Oxygen consumption was measured using a Douglas Bag system and a Miller Circuit was used for EMG integration. The results indicated that the integrated EMG of a single muscle increases linearly with increased work loads and speeds of muscular contraction. Some variations were indicated in particular muscle groups, namely the Tibialis Anterior and Gluteus Maximus, which displayed a curvilinear relationship between integrated EMG and load frequency changes. The reason given for this was the reciprocal assistance which these particular muscles received from adjoining musculature, particularly in whole body movements such as running. This argument is questionable as most muscles have reciprocal forces which might cause a similar curvilinear relationship. The integrated

EMG and oxygen consumption increased with the rate of pedaling. BIGLAND and LIPPOLD (1954), MIYASHITA (1967) and HENRIKSONN (1974) have all indicated similar relationships between integrated EMG and linear increases in work loads and the speed of muscular contraction. All of these referenced sources utilize non ballistic type movements to demonstrate the velocity EMG relationships. Whether the electrical activity in the muscle is increased in proportion to extremely high velocities during the middle and concluding periods of a ballistic movement is still open to question.

ANGEL (1975) studied the myoelectric patterns associated with ballistic movement. Eleven subjects ranging from 16 to 60 years of age performed arm movements which were controlled by passive acceleration due to the addition of an extra load or mechanical constraint. The sugject was not aware of how the movement would be varied. Surface electrodes recorded EMG potentials during each of the ballistic movements. The raw EMG was then measured for maximal and minimal deflection patterns. The velocities of the hand were measured by a transducer which moved according to the hand position during the movement. A tri phasic EMG pattern resulted with the deflection pattern peaking twice during the contraction. Each of the peaks was separated by an obvious decrease in EMG levels. Angel was unable to explain the second peak but suggested that the initial volley was the agonistic movement and the second was the controlling contraction which holds the limb in position. The subsequent fading of electrical activity after the second contraction could not be explained. It is possible that a similar phenomenon may occur in the ballistic movements of the lower extremity during the kick.

FISK (1976) recorded EMG potentials using fine wire electrodes in the triceps, flexor carpi ulnaris and flexor carpi radialis during the overarm throw. The results indicated a decreased activity level in the forearm flexors as the forearm began to move forward. Greater contraction levels were indicated in the flexors in throws involving spin and curved balls.

INMAN (1952) observed the variations in integrated EMG during changing muscle tension levels in cineplastic amputees. Fine wire copper electrodes were used to record EMG potentials which were integrated through an electronic circuit which provided a quantitative measure of amplitude variations. Integrated EMG closely paralleled tension in a given muscle contracting isometrically. Because of changing tension levels during isotonic contractions there was no relationship between tension and integrated EMG. During a rapid isotonic contraction there was a disparity between peak electrical activity and peak integrated EMG. The lag period was measured at $.08 \pm .02$ seconds irrespective of the muscle length. If the contraction was slow this lag was obscured. Time lag periods may be apparent in high velocity ballistic movements, however Inman does not report this finding during isometric contractions. Time lag between initial contraction and EMG readout would be revealed through combining high speed photography with EMG during a high velocity movement.

FINE WIRE ELECTRODES

Technological advances and improved techniques in the field of electromyography have enabled the use of fine wire implanted electrodes in obtaining concise EMG results BASMAJIAN (1971).

> "Bipolar fine wire electrodes isolate their pick-up either to the whole muscle being studied, or, if it has a multipennate structure, to the confines of the compartment within the muscle. Barriers of connective tissue within a muscle or around it act as insulation, and so one records all the activity as far as such a barrier without interfering with pick-up from beyond the barrier (such as there always is with surface electrodes." BASMAJIAN (1971:111)

Because of the requirement in the present study for EMG readings during ballistic movements, fine wire electrodes are considered more appropriate. The necessity for precise recordings from a particular muscle and the requirement for maximum electrode stability is apparent from the nature of the movement. Surface electrodes must be fixed to the skin surface and due to the fast nature of the movements could produce movement artifact. Due to the popularity of the fine wire electrode a number of studies have indicated characteristics which require consideration. DE LUCA (1973) demonstrated that when using fine wire electrodes the amplitude of the output is dependent upon the amount of insulated area on the tip of the wire. A similar variation occurs due to the thickness of the skin and underlying fat when using surface electrodes. The indication is that the amounts of insulation removed should be the same for each wire used.

JONSSON (1968) reported on the reaction of wire implants during muscular contraction. A detailed description is given concerning the construction, implantation and removal of the electrodes. (The construction and insertion methods presented by Jonsson will be used in the present study). The results indicated that the wires were displaced 14 millimetres on an average and this did not vary due to wire diameter. All wires were shown to have one or several kinks, the deformation being more predominant in the smaller diameter wires. The

frequency of wire fracture was rare and in the cases of fracture there appeared to be no more pain or tenderness than was experienced by the insertion needles.

CAVANAGH (1975) used an EMG analysis method similar to the method used in the present study. EMG records were digitized with the greatest amplitude of activity being considered as 100% and the remaining action potentials for that particular muscle considered as a percentage of the maximum. The synchronized time pulse indicated the relationship of the muscle contraction to the film records.

CHAPTER III

METHODS AND PROCEDURES

The experimental procedures used in the study are presented in the chapter under the following headings:

1) Subjects

2) Pilot Study

3) Cinematographical procedures and data analysis

4) Electromyographical (EMG) procedures and data analysis

SUBJECTS

The six subjects used in the study were chosen from a highly skilled group of rugby players who were current members of the Canadian national team and considered to be the best in Canada. These selections were based on their specialized positions within the team. All the subjects could kick with their preferred and non preferred foot. All subjects had just completed a full season of competitive club rugby and were preparing for international competition.

Elite rugby players were chosen to provide a high skill standard of performance so that coaches are able to make reference to the highest available skill levels (Table 1). Each of the six subjects were tested on each of their preferred and non preferred feet over three trials. Data are presented in graphical and raw data form for all of the six subjects. To provide a comparison of kicking performance, two subjects were chosen. The choice was based on the distances the

ball was kicked on each of the trials using both the preferred and non preferred foot. The subject who performed the best with both feet and the subject who recorded the least distance with the non preferred foot were chosen for comparison. The mean distance over three trials was taken as the subjects' score for either the preferred or non preferred foot.

The decision to use elite performers as subjects was based on an attempt to approach the highest level of kicking performance available in Canada at the specific time of testing. It is hoped that inferences can be made to less experienced and developing kickers who are presently learning the skill.

TABLE 1

SUBJECT DATA

Subject	Profession	Rugby Experience	Years Played	Weight	Height	Age
0	Amateur Sports Director	5 yrs	10 yrs	176 lbs	5'9"	26
1	Lawyer	2 yrs	12 yrs	170 lbs	5'9"	25
2	Teacher	4 yrs	9 yrs	175 lbs	5'10"	29
3	Teacher	5 yrs	11 yrs	154 lbs	5'7"	24
4	Student	2 yrs	7 yrs	164 lbs	5'11"	23
5	Teacher	10 yrs	15 yrs	170 lbs	5'10"	30

PILOT STUDY

A preliminary pilot study was conducted using one subject. The choice of testing equipment and procedures was based on the results of these tests. The location of the camera and the arrangement of test leads and wiring was finalized. Based on the nature of the parameters studied, the film speed, the number of approach steps, the critical point for starting the camera to attain maximum frame rate and general filming procedures were finalized. EMG needle insertion procedures were finalized after numerous practice sessions using the researcher's own musculature. The adjustment and standardization of amplifier and recording settings was also finalized.

CINEMATOGRAPHICAL PROCEDURES AND DATA ANALYSIS

Filming took place on a level grassed field surface. The camera used was a Photosonics 16 mm (model 1PL) fitted with a 12 - 120 mm Angenieux zoom lens. The photosonics TLG timing generator was used to mark the film and simultaneously record timing marks on the electromyographic recordings. The film used was Eastman Kodak Ektachrome 7239 (Fig. 1).

The camera was situated at 90^{o} to the subject and the lens to subject distance set at 30 metres (Fig. 4). The film speed was set at 100 frames per second and the camera was turned on as the subject passed a predetermined point the step before the kicking foot left the ground. This procedure was followed to allow the camera frame rate to stabilize as the subject's kicking leg was filmed. A

FIG. 1

16mm. - PHOTOSONICS CAMERA - 4 TRACK FM RECORDER
DUAL BEAM OSCILLOSCOPE- EMG AMPLIFIER

FIG. 2

POSTERIOR VIEW
EMG LEAD SYSTEM

FIG. 3

LATERAL VIEW
EMG LEAD SYSTEM

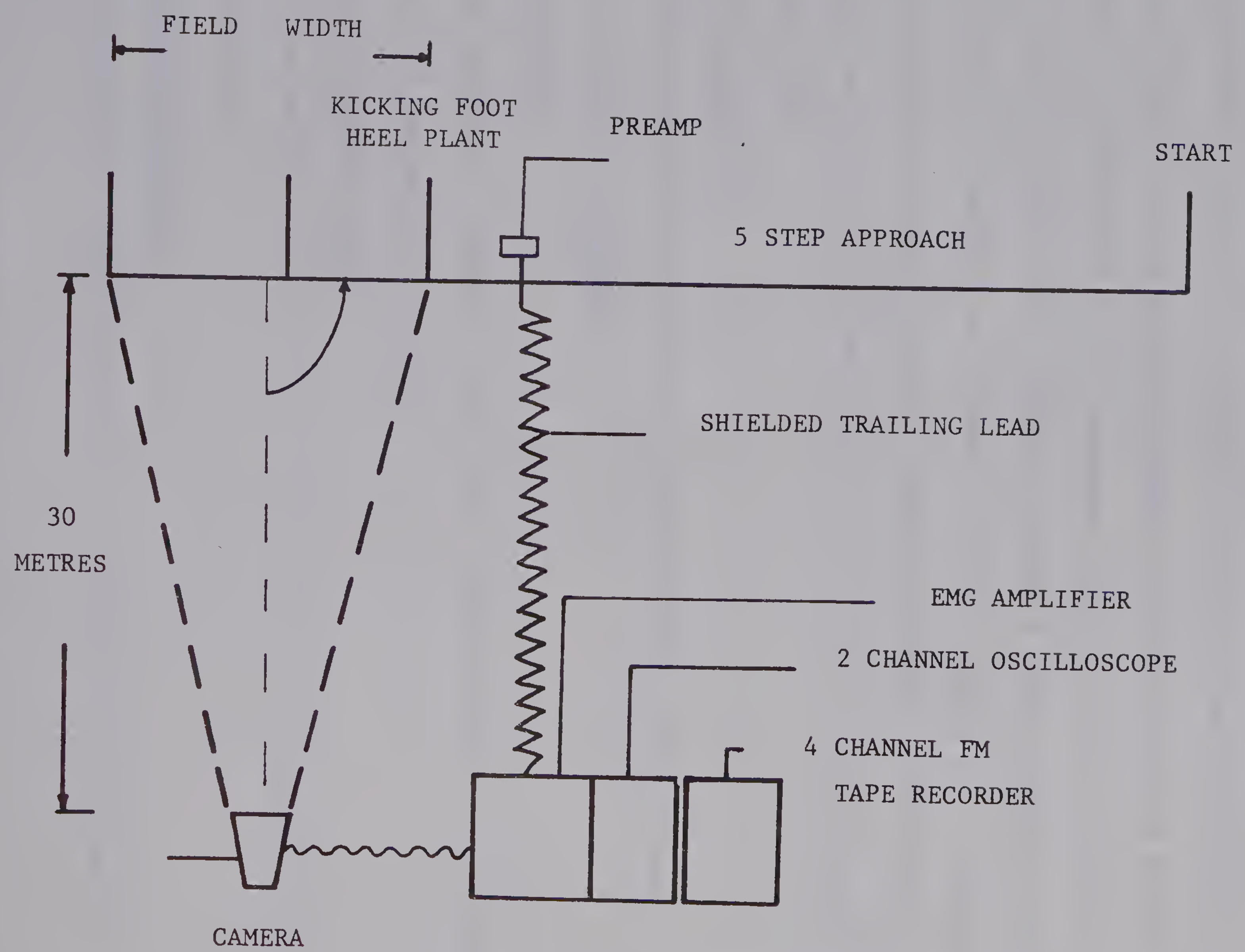


FIG. 4
CINEMATOGRAPHY AND ELECTROMYOGRAPHY FIELD SET-UP
FOR RUGBY PUNT

reference tree measure was filmed in the plane of action (Fig. 7).

Each subject was given time to warm up and practice as many kicks as needed over a fifteen minute period. Each kick was repeated three times with each leg using a five step approach. All kicks were completed for the purpose of gaining maximum distance. The kick which gained the maximum distance was chosen for analysis.

Film data reduction was completed using a 16 mm Triad VR/100 pin registered film analyzer projecting onto a Bendix digitizing board. The X and Y co-ordinates for 21 segmental end points were fed into an HP9825A Hewlett Packard Mini Computer through a 9864A Digitizer. Due to differences in subject performances critical frames were chosen for digital analysis on each subject. Comparative differences between the following variables were demonstrated for both the preferred and non preferred foot.

Angular Acceleration

The sequential changes in the angular velocity of the trunk, thigh, leg and foot segments.

Linear Velocity

The sequential changes in the linear velocity of the trunk, thigh, leg and foot segmental end points.

Velocity of Centre of Mass

The sequential changes in the linear velocity of the centre of mass of the body.

Joint Angle Displacement

The sequential changes in trunk, hip, knee and ankle ranges of mobement.

The critical frames chosen for digitizing were:

1) The instant the kicking foot left the ground.

2) The first hand released from the ball.

3) The instant the kicking foot heel plant took place.

4) The highest point of the ball during the carry.

5) Ball release.

6) Support foot heel plant.

7) Full flexion of the knee joint of the kicking foot.

8) The point of maximum thigh flexion before leg extension of kicking foot.

9) Impact of foot and ball.

10) Ball flight.

PROGRAMMED DATA ANALYSIS

The HP9825A mini computer was programmed to give raw data output on all body segments. This raw data was programmed to give:

1) Centre of Mass displacement and velocity changes.

2) Angular Kinematics including angular velocity and acceleration.

3) Linear Kinematics for linear velocity and displacement.

4) Joint angle displacements.

5) Electromyography measurement of paper read-out recordings of limb segment musculature.

Procedures

Data smoothing calculations were performed on the raw data for angular acceleration and the centre of mass velocity curves. The first finite difference method was used to smooth angular acceleration curves from angular velocity raw data. This method was also used

on centre of mass displacement raw data for centre of mass velocity curves.

Centre of Gravity locations and body segment weights for Centre of Mass calculations are based on M.I.T. scales (NIELS, 1974), (Fig. 10 and Table 2).

ELECTROMYOGRAPHICAL PROCEDURES AND DATA

Analysis

The musculature chosen for EMG analysis during the kick was based on accessibility of the muscle belly and the prime functions of the muscle. The number of muscles was limited to three due to the limited number of channels available on the recording device. The EMG analysis was based on musculature controlling the trunk and the three major segments of the lower extremity, the thigh, the leg and the foot.

The three muscles used for the present study included the Rectus Femoris, Biceps Femoris and Tibialis Anterior. The two joint characteristics of both Rectus Femoris and Biceps Femoris indicate functional control over both the hip, the knee and to some degree the trunk. The Tibialis Anterior crosses only the ankle and therefore has an influence over the one joint only (BASMAJIAN, 1974: BOS, 1970; JACKSON, 1972).

The motor points of each muscle were approximated by taking mid point measurements between the proximal and distal bony point attachments (Figs. 2 & 3). The motor points were marked as a site for electrode insertion using the guidelines of GOODGOLD (1974).

The electrodes chosen for the present study were the bipolar fine wire type developed by BASMAJIAN (1974). The construction of

the electrodes was based on the description given by JONSSON (1968) and the insertion techniques used by the same author were also adopted for the present study. The attachment of the fine wire electrodes to the EMG leads and pre-amplifier system was accomplished by soldering small mild steel springs to an insulated plastic strip which also carried a ground electrode on its base. Sterile conditions were maximized by soaking the disposable 26 gauge hypodermic needles and the two fine wires inside the needles, in a bath of ethanol for a minimum of eight hours. The fine wires were cut to approximately 5 inches to allow for movement within the muscle belly (Fig. 6).

The EMG measurement system used for the amplification of the EMG signals was a four channel trail lead system designed for free movement in a field situation. The component parts of the system consisted of 4 compact pre-amplifiers housed in a small plastic box measuring 12 x 6 x 4 cm and weighing approximately .25 kg. The pre-amplifier was mounted on the subject's lower back where it caused minimal hindrance to movement. The pre-amplifier was designed for carrying low output impedance along a 50 foot, 4 conductor, shielded, phonograph, pickup cable. The amplifier system received the four cables through a 60 Hertz filtering system into 4 separate amplifiers. Each amplifier was equipped with a gain control to balance the differences in individual muscle readings and resistance (Fig. 9). The light nature of the cable and the compactness of the pre-amplifier created minimal impediment to the subject (SPRIGINGS, 1977).

A two channel oscilloscope (Tektronix Type Dual Beam 502) was used to monitor the EMG readings and ensure that each channel was

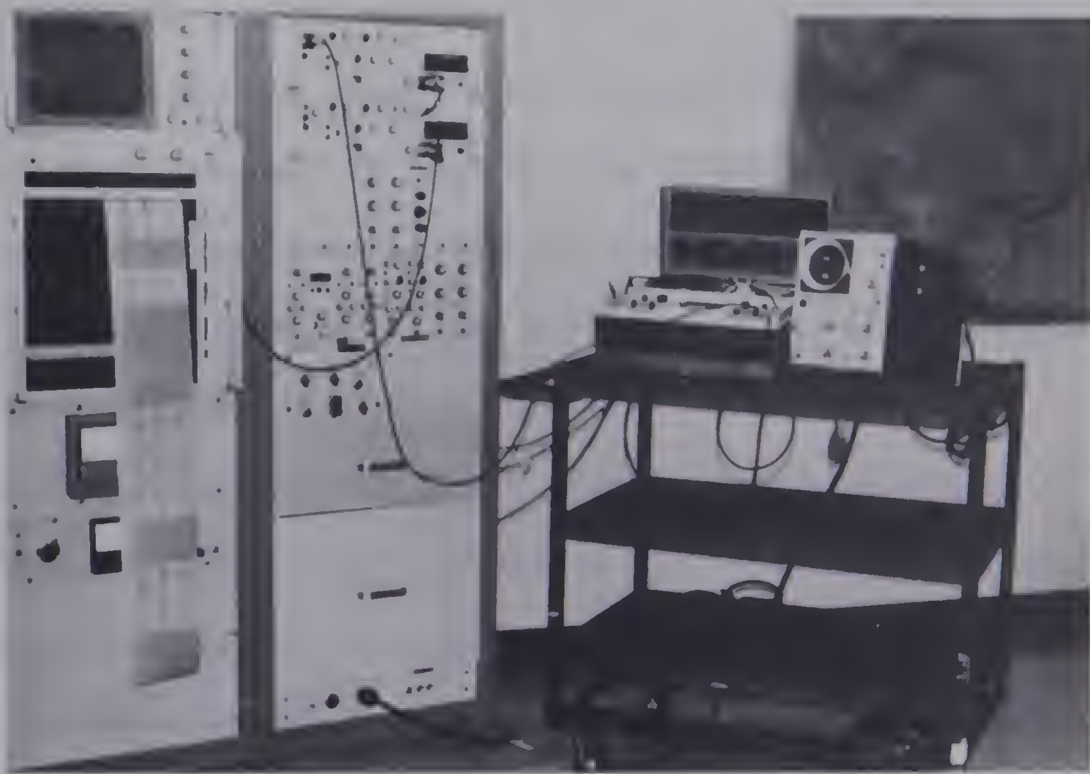


FIG. 5

4-TRACK FM TAPE RECORDER RECORDING INTO HONEYWELL ELECTRONIC MEDICAL SYSTEM

FIG. 6

FINE WIRE ELECTRODES AND COUPLING UNITS FOR ELECTROMYOGRAPHIC RECORDINGS

functional. Head phones were also attached to each amplifier to provide an additional monitoring device. When the four channels were providing a clear output of muscular contraction the amplifier leads were attached to a 4 channel FM tape recorder (Hewlett Packard 3960 series) to provide a permanent storage of the EMG output. The tape speed was set at dial reading of 3.75 and was capable of recording input from 0 to 1250 Hz. The tapes were then played back into a Honeywell Electronic Medical System to provide permanent visual recordings on the oscillograph provided in the system (Fig. 5). The paper readout provided a permanent visual result of the EMG readout for future reference (Fig. 8). The timing system used to coordinate the EMG readout to the camera was based on the Photosonics TLG timing system which simultaneously pulsed 100 Hz light markings onto the film and registered on impulse on one channel of the tape recorder. As the subject approached the filming mark the timer was switched to 1000 Hz then back to 100 Hz to indicate the start of the kicking motion. Using this system the three channels of EMG could be identified with each frame on the film (Fig. 7).

ANALYSIS OF EMG DATA

The paper readout provided muscle action potential recordings of the three muscles tests (Fig. 8). The paper recordings were analyzed by attaching the readout sheets to the digitizing board and then using a programmed method to record maximum EMG peaks over time (Appendix F). Artifact and noise levels were digitized and subtracted from the total maximum digitized and subtracted from the total maximum EMG percentage

levels on each of the three muscles tested. A graphical representation of each EMG level was then produced indicating fluctuating levels over the same time period as the kinematic variables which were also being measured (Figs. 18 to 21).

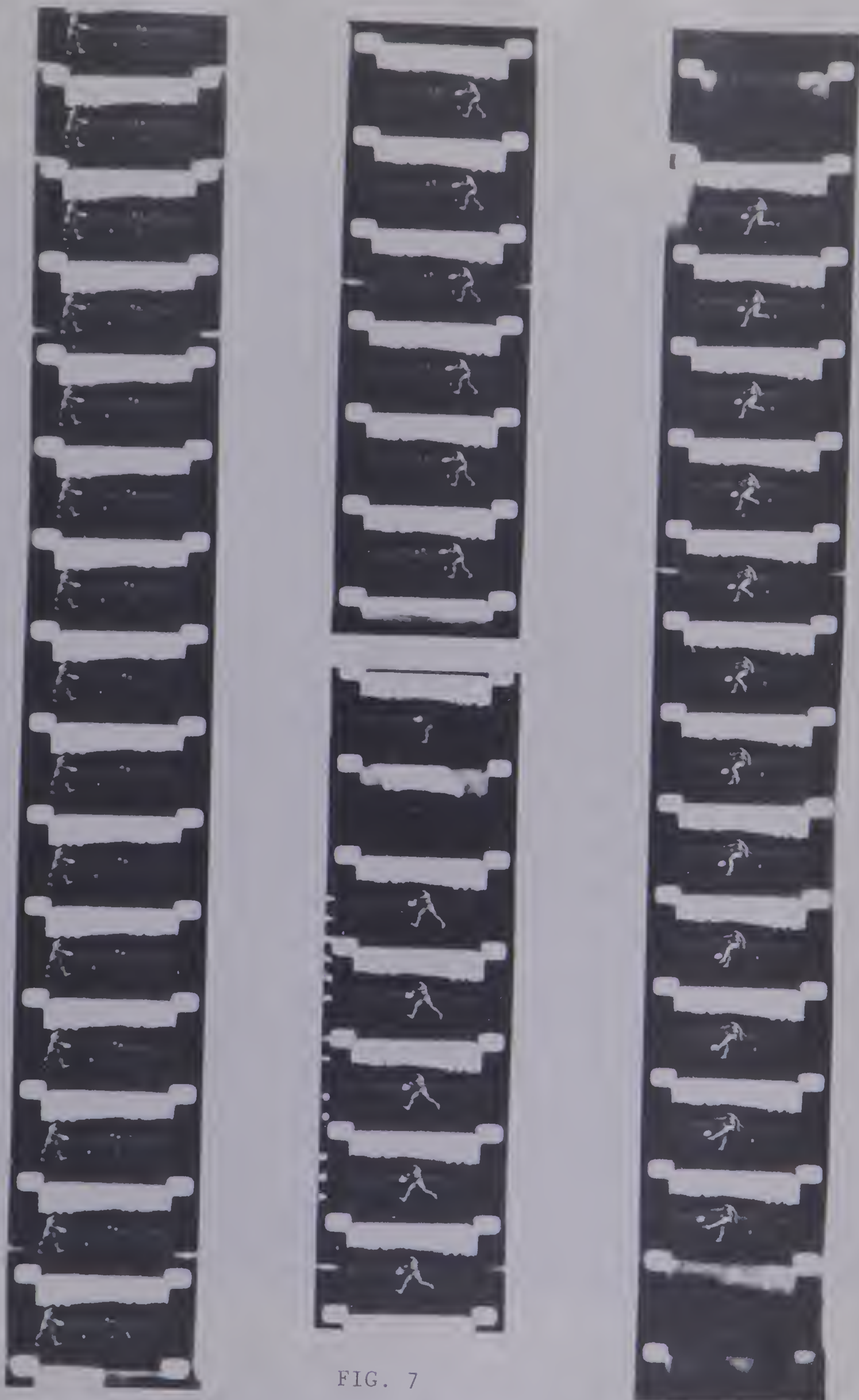


FIG. 7

SUBJECT O FILMSTRIP - TIMING MARKS INDICATED
TO SIDE OF FRAMES

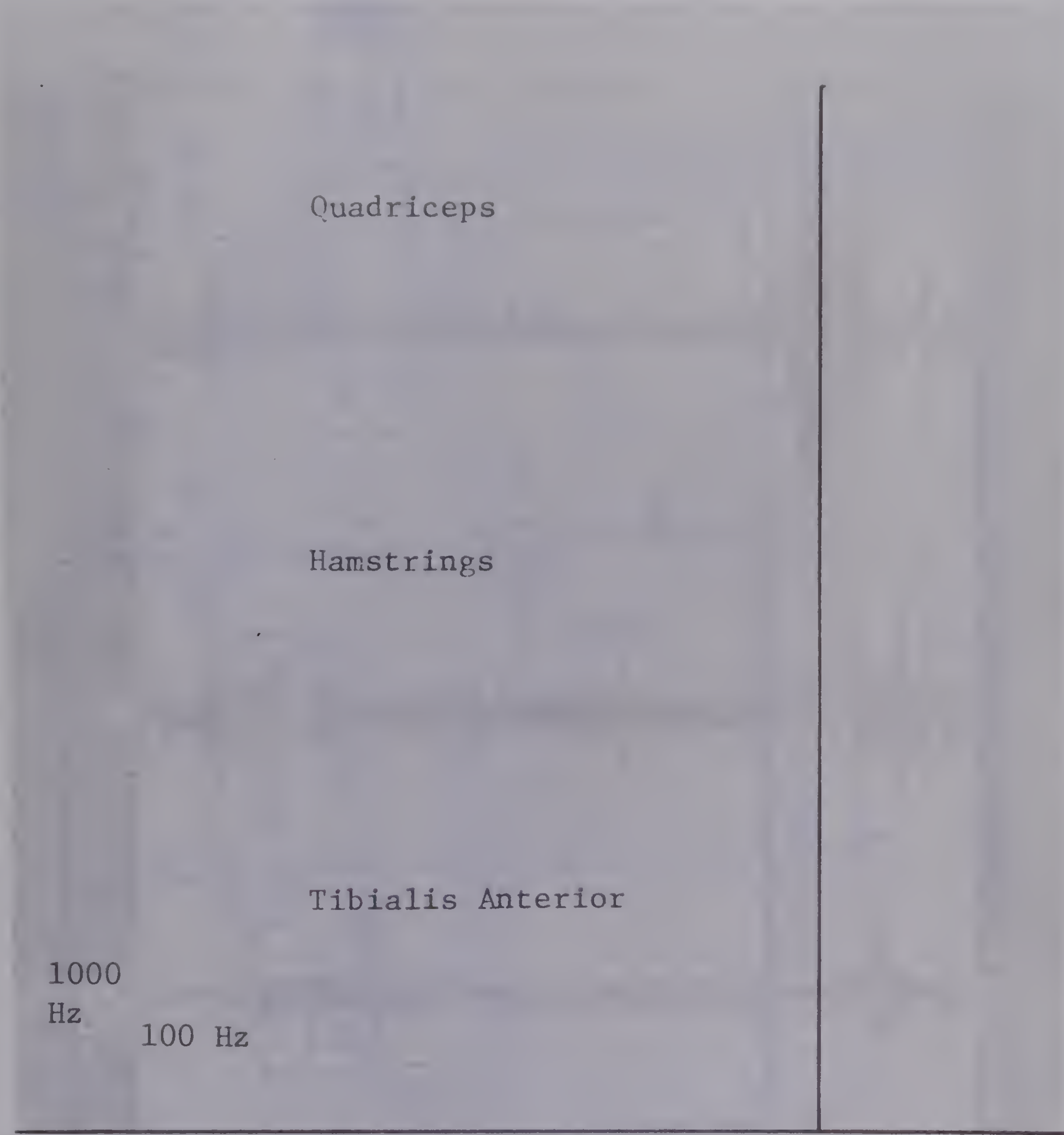


FIG. 8
ELECTROMYOGRAPHIC RECORDING - RUGBY PUNT

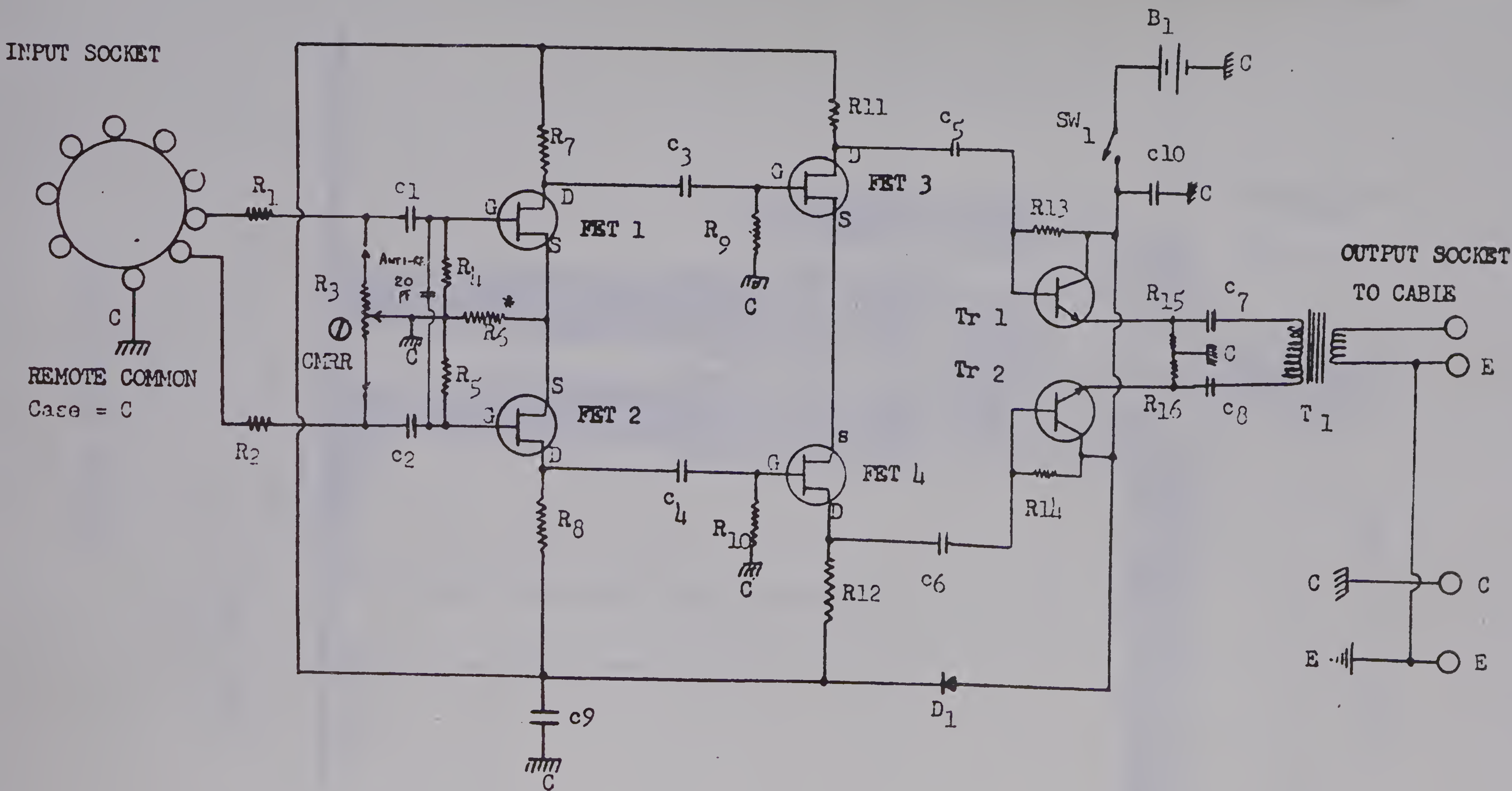
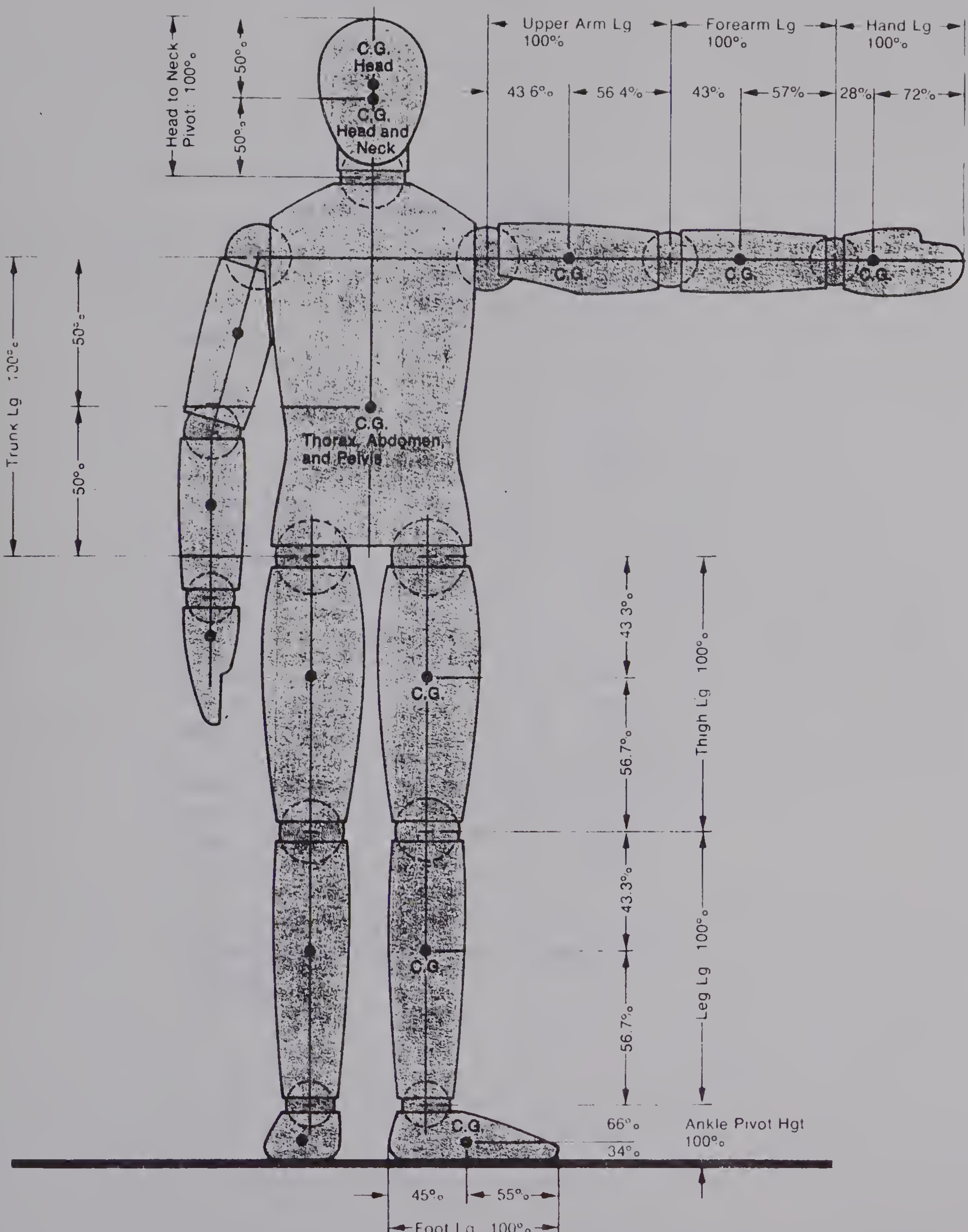


FIG. 9

SCHEMATIC DIAGRAM-EMG-REMOTE TRANSPONDER UNIT



(NIELS, 1974)

FIG. 10

CENTRE OF MASS LOCATIONS

BODY SEGMENT WEIGHTS

	MALE	FEMALE
Head	7.1	* 5.7
Neck	2.5	* 2
Trunk	45.8	46.3
Upper Arms	6.6	6
Forearms	3.8	3.1
Hands	1.3	1
Thighs	21	23
Legs	9	10.5
Feet	2.9	2.4
Total	100%	100%

* Estimated Proportion of Head and Neck

TABLE 2

BODY SEGMENT WEIGHTS

CHAPTER IV

RESULTS AND DISCUSSION

Kinematic and Electromyographic Data Comparison - Subjects 1 and 4

The results presented were based on the kicking performances of six elite subjects. Each subject was filmed over a series of three trials on both the preferred and non preferred foot. The ball displacement of each kick was recorded (Table 3). Each subject was wired to give electromyographical recordings from the kicking leg. Based on displacement of the ball the best trial for both the preferred and non preferred foot of each subject was chosen for further analysis (Table 3).

Comparing the distances the ball is kicked, the subject who, over three trials, indicated the least difference between the preferred and non preferred foot (subject #1) and the subject who indicated the greatest difference (subject #4) were chosen for specific comparison (Table 3).

Kinematic and electromyographical data is presented for the two subjects chosen for comparison (subjects 1 and 4). Angular accelerations of the trunk, thigh, leg and foot, linear velocities of the trunk, thigh, leg and foot segmental ends, velocities of the centre of mass and angular range of motion of the trunk, hip, knee and ankle were the kinematic parameters presented. Electromyographical data for the Rectus Femoris, Biceps Femoris and Tibialis Anterior muscles is presented with angular velocity variations for the hip, knee and ankle. Results are presented in both raw data and graphical form.

KICKING DISTANCES FOR PREFERRED AND NON PREFERRED FOOT

SUBJECT	FOOT	TRIAL		Metres	$\bar{X}$
0	PREF	1	*	62	
		2		59	60.3
		3		60	
	NONPREF	1		55	
		2		56	56.3
		3	*	58	
1	PREF	1	*	67	
		2		65	63.6
		3		59	
	NONPREF	1	*	59	
		2		57	58
		3		58	
2	PREF	1		58	
		2		57	57.6
		3	*	58	
	NONPREF	1		46	
		2		43	46.3
		3	*	50	
3	PREF	1		56	
		2	*	59	55.6
		3		52	
	NONPREF	1		43	
		2		48	47.0
		3	*	50	
4	PREF	1		54	
		2	*	58	55.6
		3		55	
	NONPREF	1		43	
		2		35	41.3
		3	*	46	
5	PREF	1		56	
		2		58	58.0
		3	*	60	
	NONPREF	1		50	
		2	*	50	48.6
		3		46	

* Subject trials chosen for analysis

TABLE 3

Kinematic and electromyographic data is also presented for subjects 0, 2, 3 and 5. Angular accelerations of the trunk, thigh, leg and foot; linear velocities of the trunk, thigh, leg and foot; velocities of the centre of mass and angular ranges of motion of the trunk, hip, knee and ankle are given. Electromyographical data for the Rectus Femoris, Biceps Femoris and Tibialis Anterior muscles is presented with the angular velocity variations of the trunk, thigh, leg and foot (Appendix E).

Data is reported with reference to the kicking foot, heel plant (K.F.H.L.); support foot heel plant (S.F.H.L.); full lower leg flexion (F.L. FLX.); thigh flexion immediately before contact (T.FLX.) and contact of foot and ball (C.N.T.) The sequential variation in the kinematic variables of the limb segments is discussed with reference to:

1) the instant the kicking foot leaves the ground
2) the swing phase between kicking foot heel plant and support foot heel plant
3) the instant of foot heel plant
4) the motion from support foot heel plant to leg and thigh flexion to contact of the kicking foot

<u>Angular Accelerations - Subjects 1 and 4</u>

The variation in velocities of the body segments at each of the joints was measured in radians per second per second. The angular acceleration of the trunk and thigh was measured with respect to the horizontal while moving in the saggital plane. Both the leg and the foot were also measured during motion around a transverse frontal axis

in the saggital plane.

Based on the kicking distances recorded (Table 3) for all subjects on each of three trials, Subject 1 was classified as the superior kicker. The variations in angular velocities for both the preferred and non preferred feet for Subjects 1 and 4 are presented in graphical form. Changes in the angular velocities for the trunk, the thigh, the leg and foot are presented (Figs. 11 and 12).

Trunk accelerations for Subject 1 indicate very similar patterns from kicking foot heel plant to support foot heel plant for both preferred and non preferred feet. After support foot heel plant there is a slightly greater deceleration on the non preferred side followed by an acceleration to contact for both feet. Thigh acceleration patterns are similar for both sides up to flexion of the leg when the preferred side demonstrates a slightly higher acceleration followed by an equally high deceleration to contact. Leg accelerations also follow a similar pattern for both the preferred and non preferred sides. Identical deceleration then acceleration occur for both feet before and after support foot heel plant. The leg is decelerating on contact for both left and right feet. Maximum acceleration of both the preferred and non preferred legs is shown approximately mid way between full leg flexion and contact. The foot segment accelerations demonstrate very similar patterns with greater positive accelerations for the preferred foot. Both feet are decelerating on contact.

The fluctuating relationships of the segmental acceleration pattern are almost identical for both the left and right foot for Subject 1. The non preferred foot initiates thigh acceleration slightly earlier than the preferred, and the subsequent leg and foot accelerations

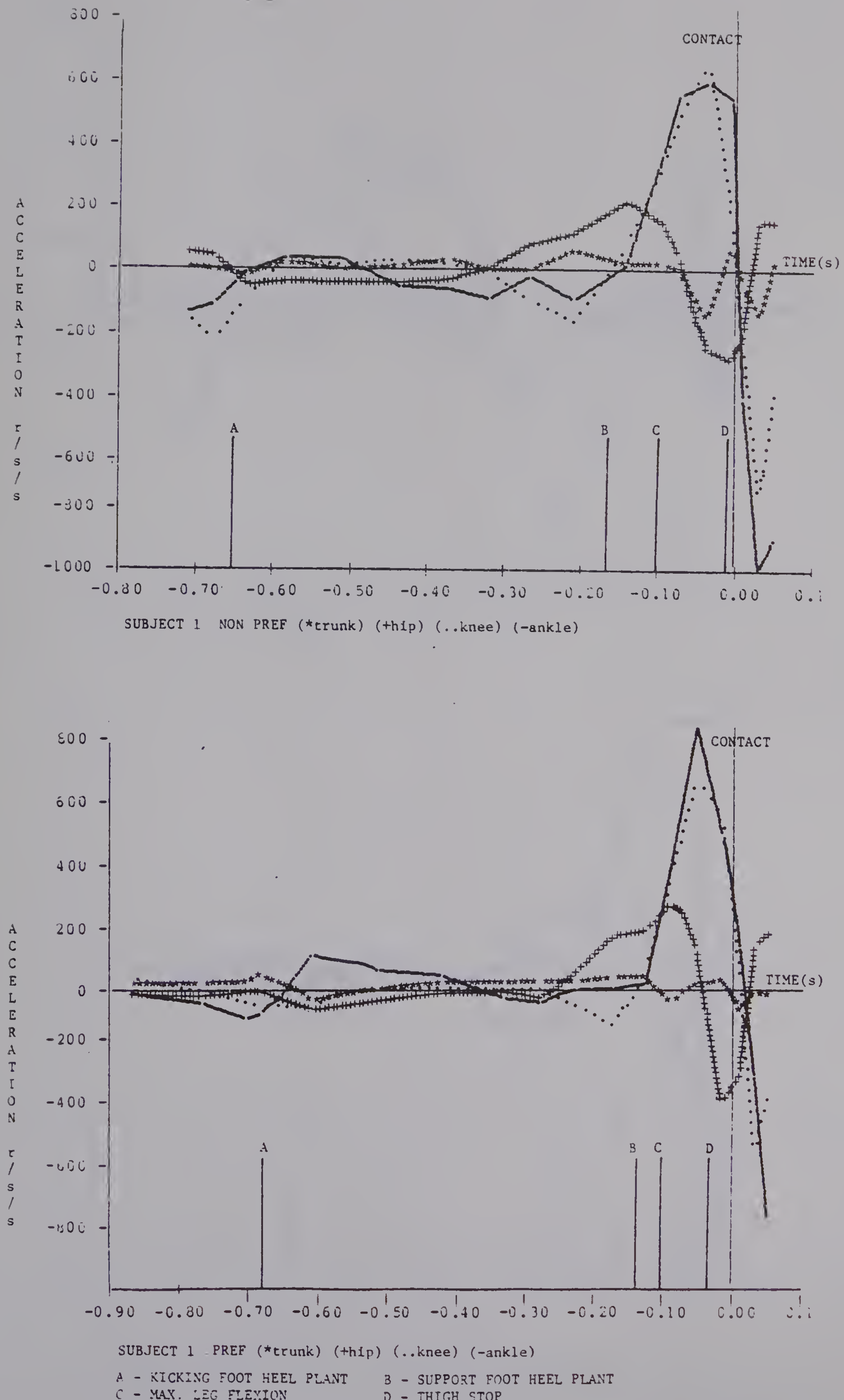


FIG. 11 ANGULAR ACCELERATIONS - SUBJECT 1 NON PREF & PREF FOOT

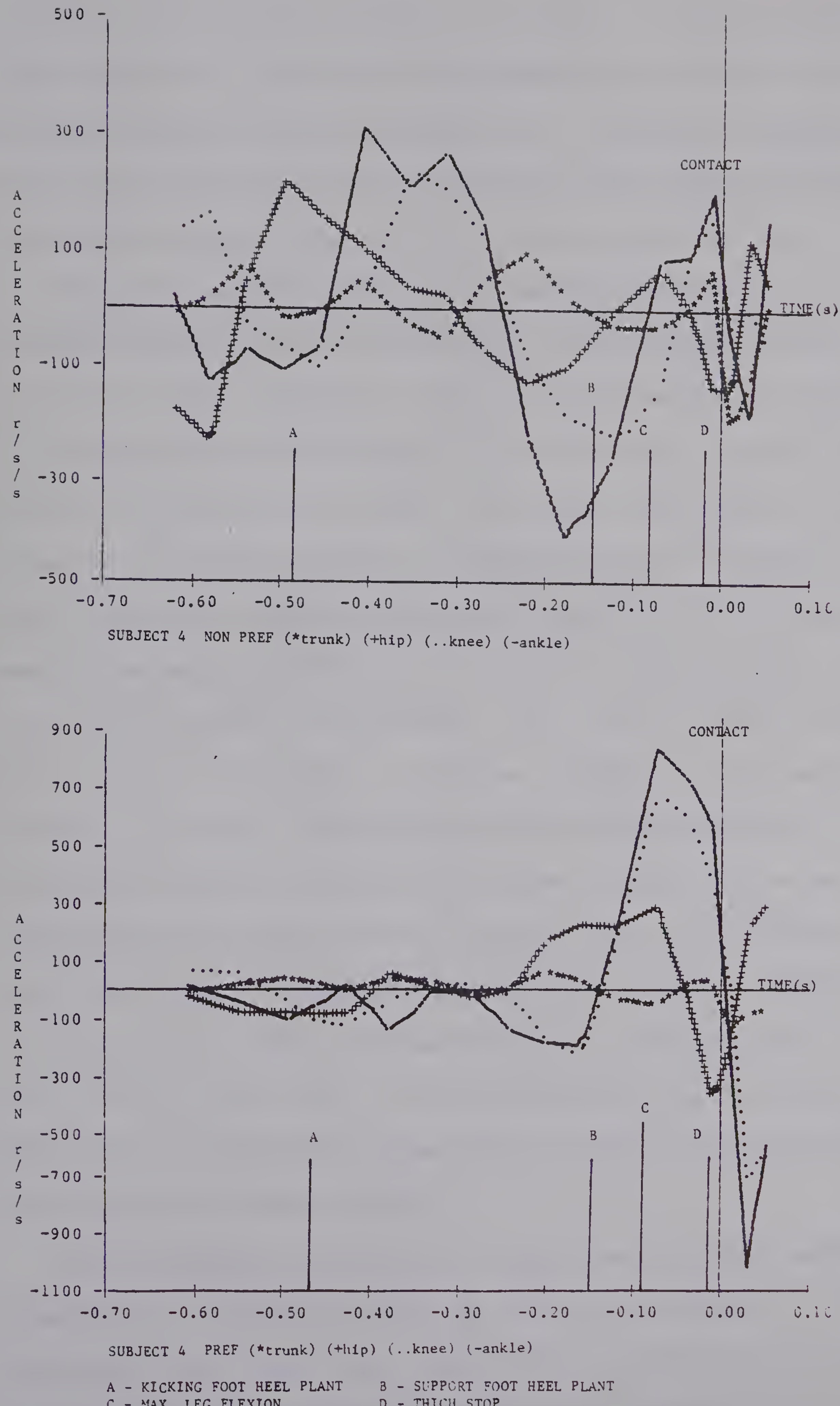


FIG. 12 ANGULAR ACCELERATION - SUBJECT 4 NON PREF & PREF FOOT

increase in very similar patterns for both feet. Thigh acceleration begins immediately before the trunk segment decreases its velocity in both the preferred and non preferred foot. Leg and foot segments rotate with increasing velocity immediately before thigh deceleration in the preferred and slightly after in the non preferred foot.

Subject 4 recorded consistently lower kicking distances for the non preferred foot and was classified as the inferior performer of the six subjects tested (Table 3). Trunk accelerations for the preferred and non preferred kicks of Subject 4 indicate similar patterns from kicking foot heel plant to contact. The major differences are demonstrated by the greater extremes in acceleration and deceleration of the trunk, particularly between kicking foot heel plant and the swing phase of the non preferred foot. The trunk is decelerating on ball contact for both left and right feet. The velocity changes on thigh motion at the hip of Subject 4 indicates considerable differences between the two sides. The non preferred thigh indicates high acceleration levels during the early stages, however they become significantly lower after support foot heel plant. The preferred thigh decelerates to a greater degree prior to contact. The foot and leg segments show similar extremes during the initial kicking foot heel plant and swing stages of the non preferred foot of Subject 4. Accelerations for both the leg and foot of Subject 4 are higher for the preferred foot before contact.

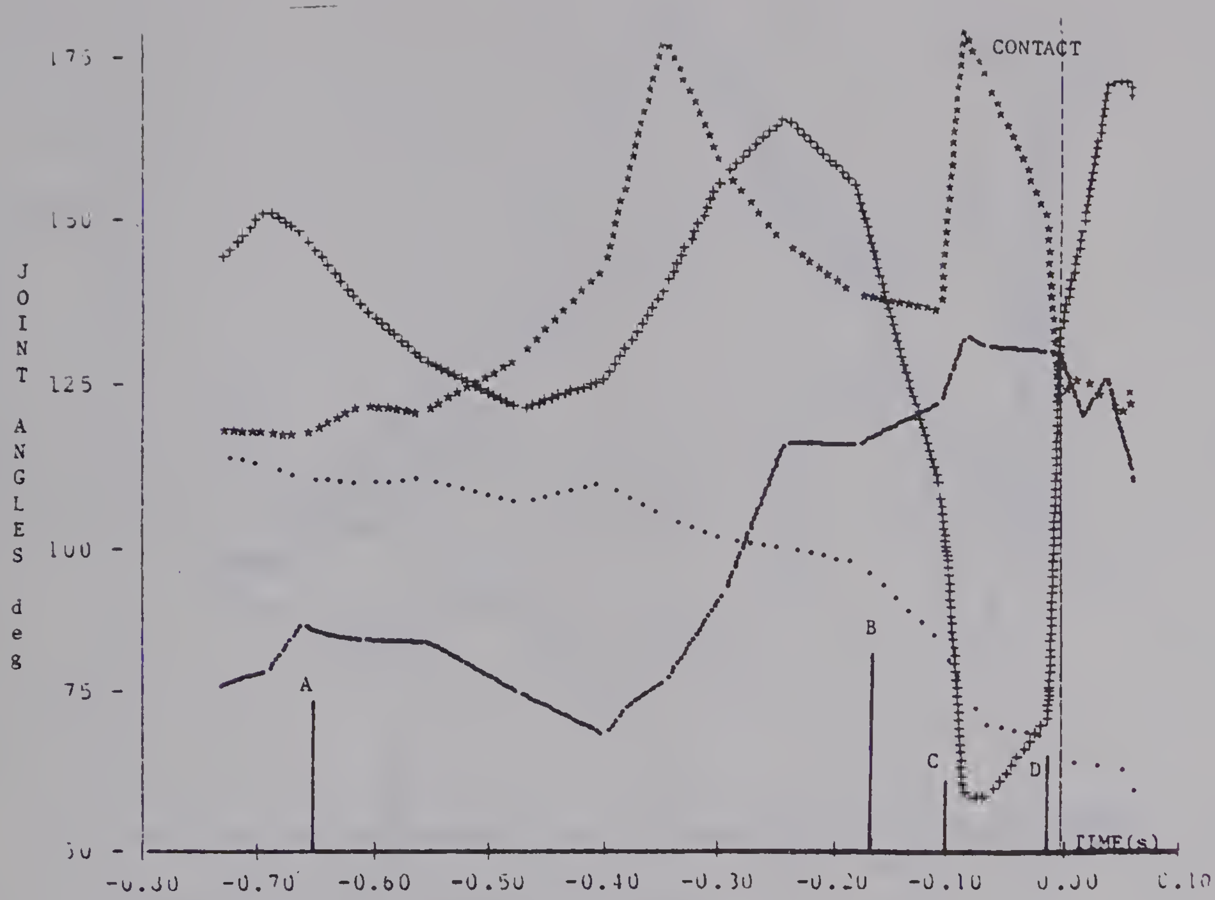
The fluctuating relationship of segment accelerations indicate a considerable difference between the two feet of Subject 4. Extreme variations in the trunk, thigh, leg and foot of the non preferred side are shown, and the maximum acceleration of the foot is

considerably lower for the non preferred side. The non preferred foot demonstrates little similarity to the sequential pattern for Subject 1. The segment acceleration sequencing pattern for Subject 1 preferred and non preferred and Subject 4 preferred have similar characteristics.

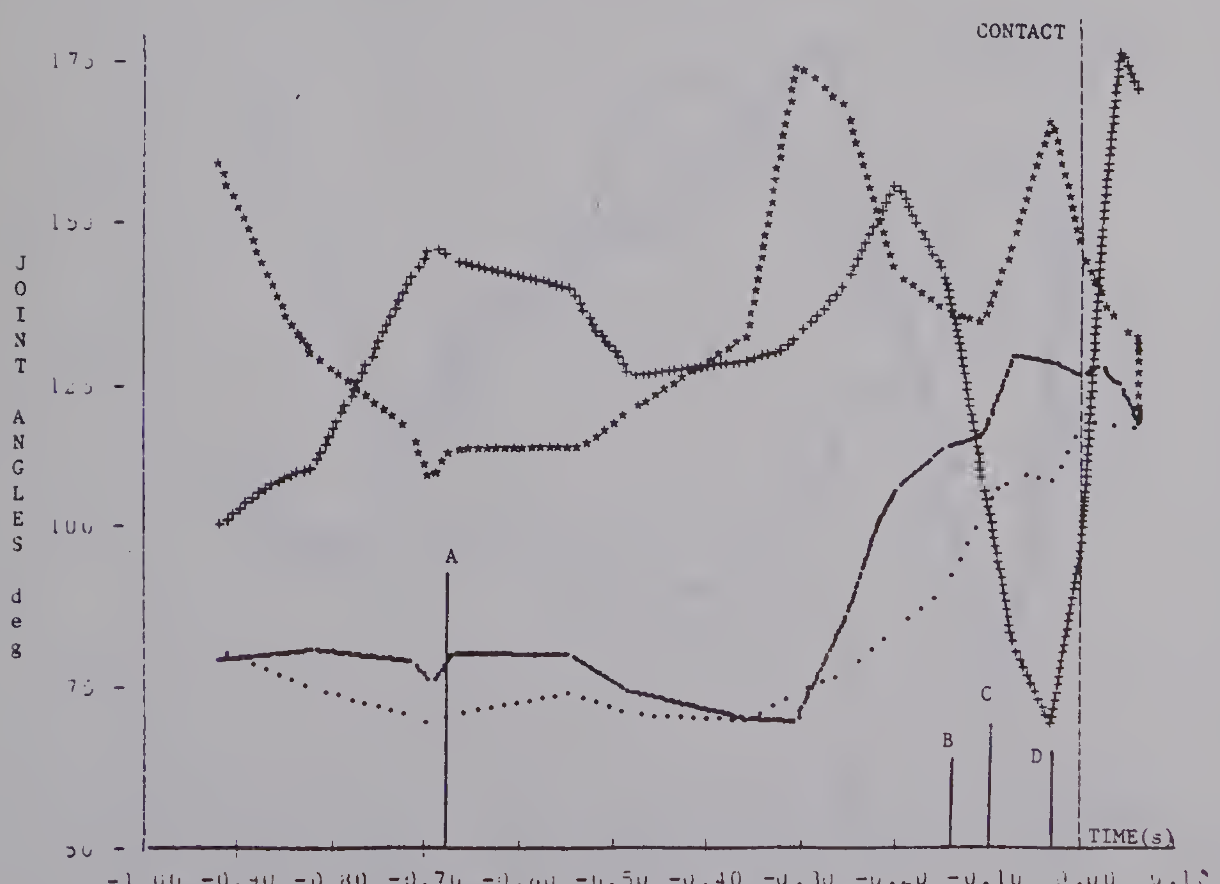
Angular Range of Joint Motion - Subjects 1 and 4

The angular ranges of motion for the trunk and thigh at the hip, the leg at the knee, and the foot at the ankle were measured in degrees. Each segment was measured with reference to motion in the saggital plane around a transverse frontal axis. Subject 1 was classified as the superior kicker based on the kicking distances recorded (Table 3). The angular ranges of motion of the preferred and non preferred foot for Subjects 1 and 4 are presented in graphical form. Angular ranges of the trunk and thigh at the hip, the knee joint and the ankle are shown in Figs. 13 and 14.

The changes in the angle range at the hip during thigh rotation for Subject 1 indicate similar patterns for both feet from kicking foot heal plant through to ball contact. Maximum joint range for both the preferred and non preferred feet occurred during hip extension just before support foot heel plant. As the knee angle decreases, the hip angle also is reduced but increases again in preparation for leg extension and contact. The hip angle ranges for thigh motion are similar for both feet for Subject 1. The non preferred foot indicates a slightly greater range in thigh extension in preparation for the swing through and ball contact. The rotation of the leg and the knee indicates similarities between the preferred and non preferred sides. Maximum knee flexion occurs simultaneously with maximum thigh extension and the angular ranges are greater in the



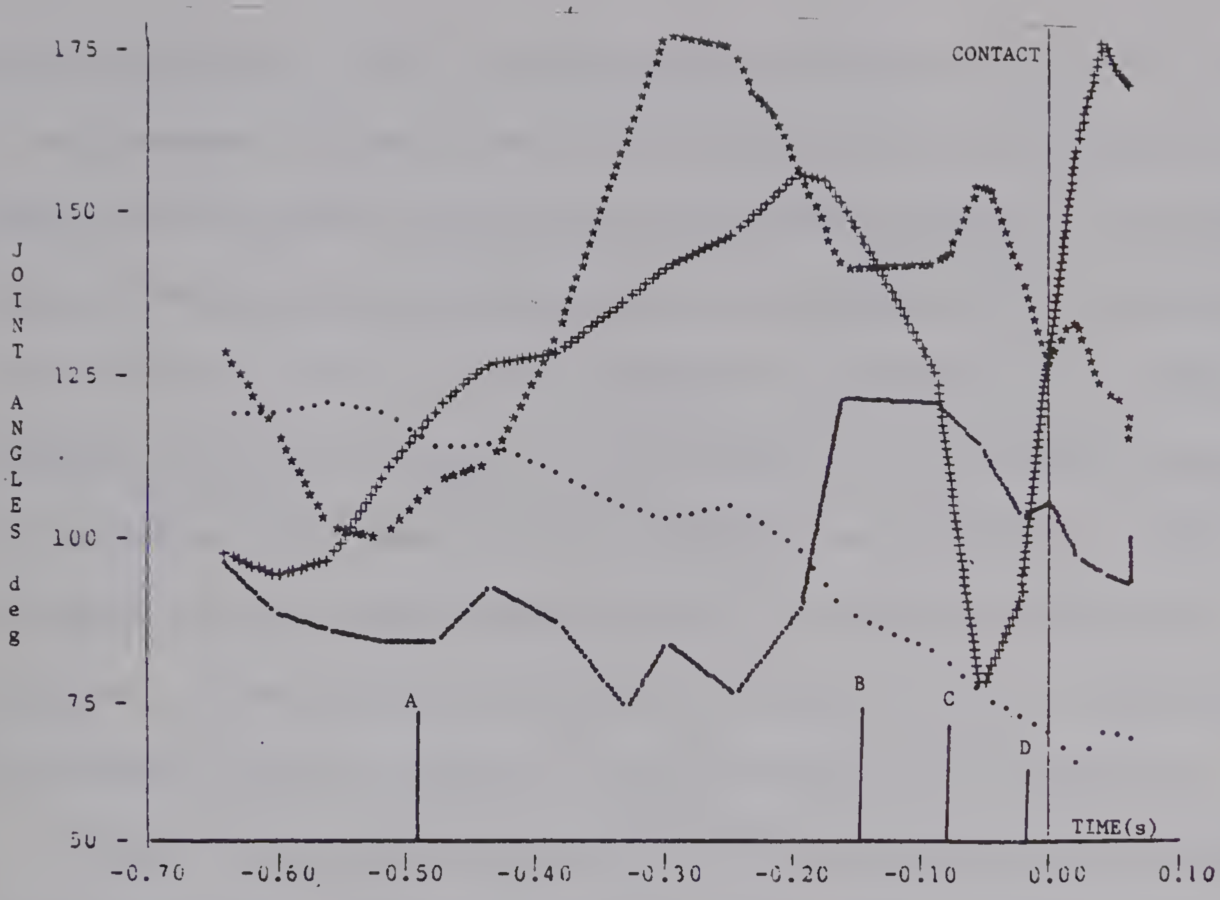
SUBJECT 1 NON PREF (*hip) (+knee) (..trunk) (-ankle)



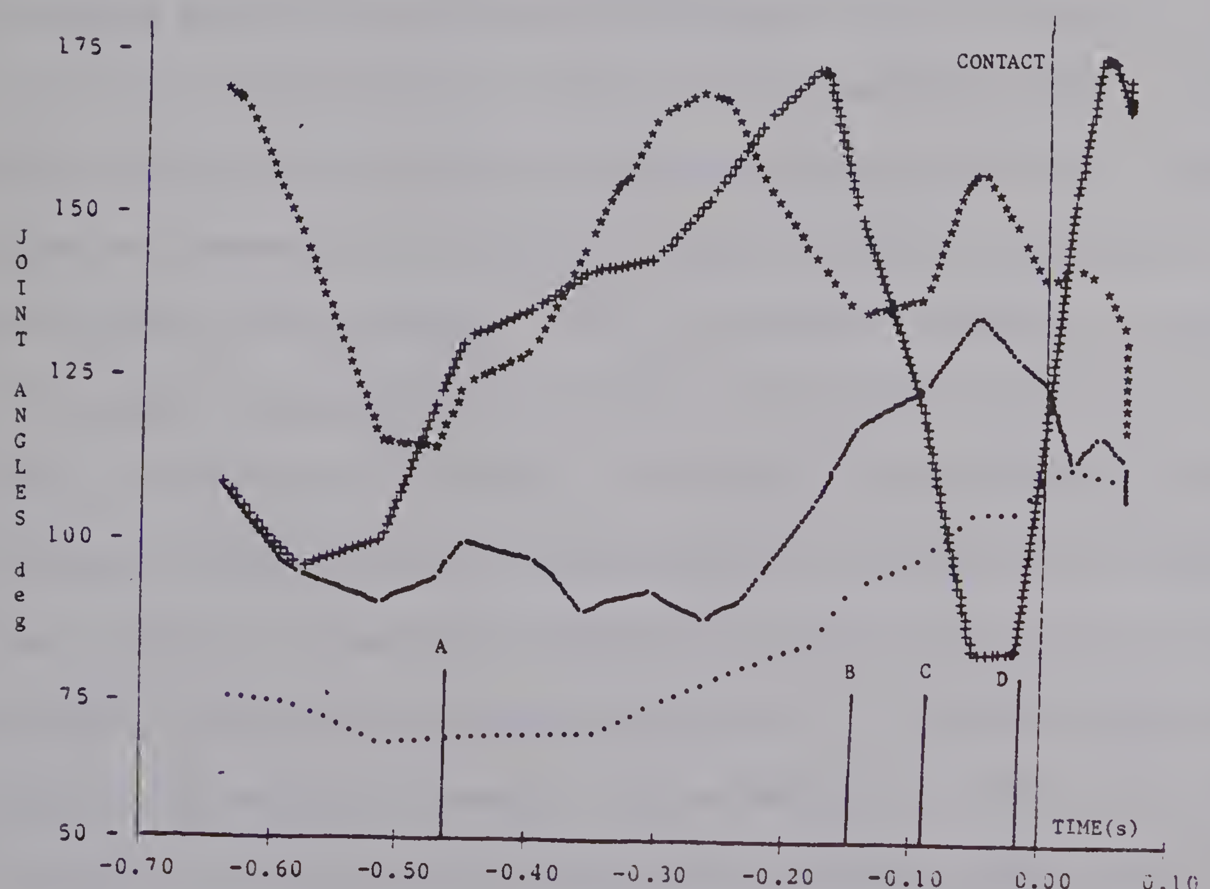
SUBJECT 1 PREF (*hip) (+knee) (..trunk) (-ankle)

A - KICKING FOOT HEEL PLANT B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION D - THIGH STOP

FIG. 13 JOINT ANGLE RANGES - SUBJECT 1 NON PREF & PREF FOOT



SUBJECT 4 NON PREF (*hip) (+knee) (..trunk) (-ankle)



SUBJECT 4 PREF (*hip) (+knee) (..trunk) (-ankle)

A - KICKING FOOT HEEL PLANT
B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION
D - THIGH STOP

FIG. 14 JOINT ANGLE RANGES - SUBJECT 4 NON PREF & PREF FOOT

non preferred foot. The foot increases its angle at the ankle starting mid way between the heel plant of the kicking foot and support foot and remains in an extended position up to and during contact. The trunk angle at the hip decreases during the non preferred kick and increases during the preferred kick. The segmental variations in the joints for Subject 1 are almost identical for both feet with knee range increases and decreases coinciding with hip decreases and increases. Ankle variations are also very similar and ball contact is at maximum extension. Trunk motion variations at the hip show the major differences between the preferred and non preferred feet of Subject 1.

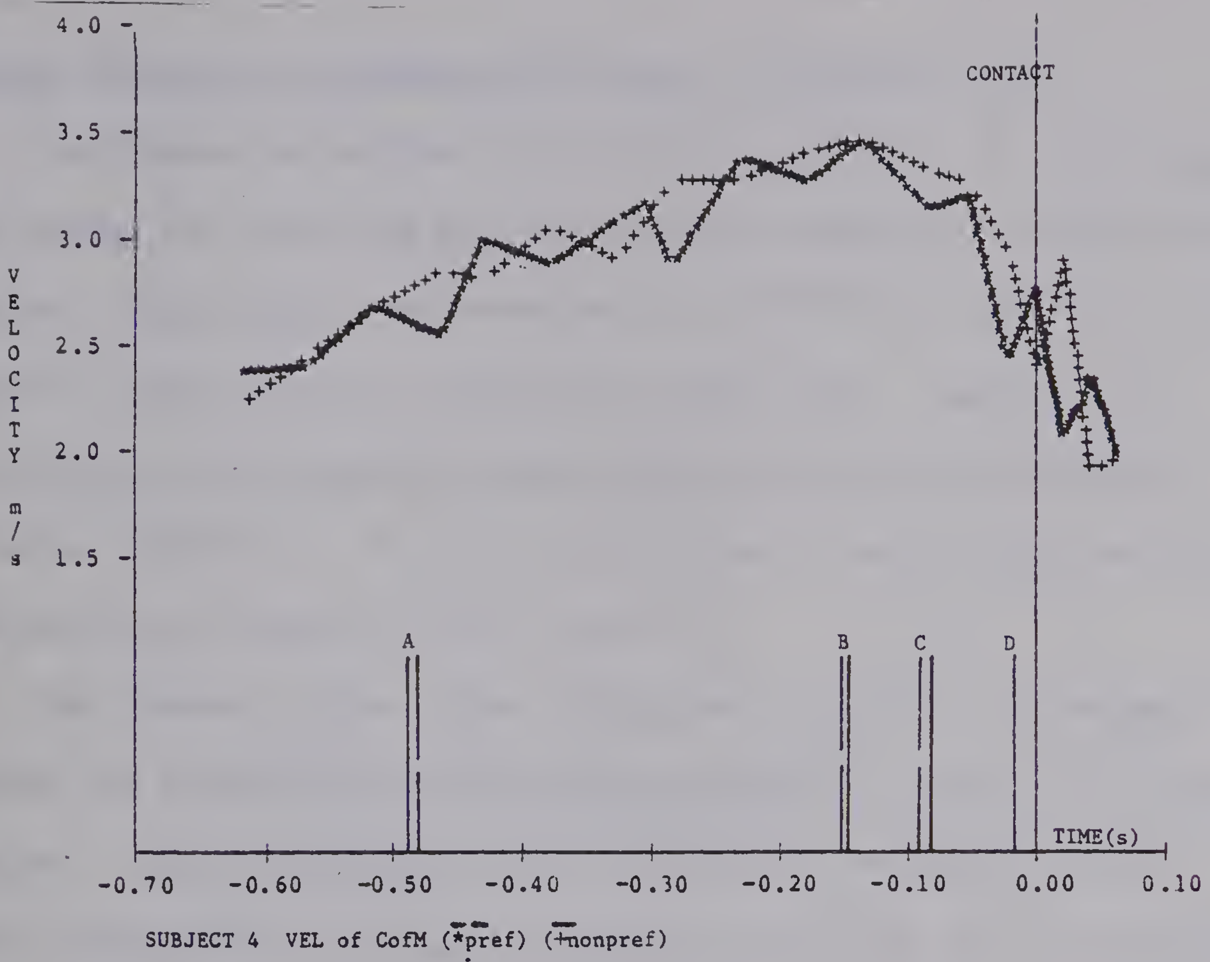
Subject 4 was classified as the inferior kicker based on kicking distances recorded (Table 3). Angular ranges for the thigh at the hip during the preferred and non preferred kicks for Subject 4 indicate limited thigh extension during the non preferred kick. A slightly higher range of motion occurs with the preferred side hip. Smaller ranges are demonstrated on the non preferred knee at the point of full knee flexion before contact. The foot segment increases its range at the ankle for both feet but levels off markedly for the non preferred foot before ball contact. The trunk angle at the hip gradually decreases during the non preferred kick but increases on the preferred side. Subject 4 generally demonstrates lower angle ranges in the knee and particularly the hip before ball contact. The ankle angles are markedly decreasing on contact. The sequential peaking of each joint is similar on both the non preferred and preferred sides except for the trunk which is decreasing at the hip before and during contact of the non preferred foot.

Velocity of the Centre of Mass - Subjects 1 and 4

The velocity changes for the centre of mass for each subject was measured in metres per second and calculations for the centre of mass of the body segments were based on the MIT scale (Fig. 10). The velocity of the centre of mass was measured using segmental motion in the saggital plane. Centre of mass velocities are shown in graphical form for Subjects 1 and 4 non preferred and preferred feet (Fig. 15).

Subject 1 was classified as the superior kicker based on the kicking distances recorded. The centre of mass velocity changes for the preferred and non preferred foot of Subject 1 show steady increases from kicking foot heel plant to support foot heel plant. The preferred foot centre of mass indicates considerably higher velocities during the remainder of the movement to ball contact. There is a noticeable decrease then increase of the centre of mass from the forward thigh position before leg extension on the preferred side. The non preferred foot does not show this change during the later stages of the movement.

Subject 4 was classified as the inferior kicker based on the kicking distances of the subjects tested. The centre of mass velocity curves are consistently equal from kicking foot heel plant to support foot heel plant for both feet then the non preferred velocities are slightly higher. Both centres of mass reduce their velocity after support foot heel plant, the preferred foot indicating an increasing velocity to contact. Both the non preferred and preferred feet of Subjects 1 and 4 show similar characteristics in the centre of mass velocity variations.



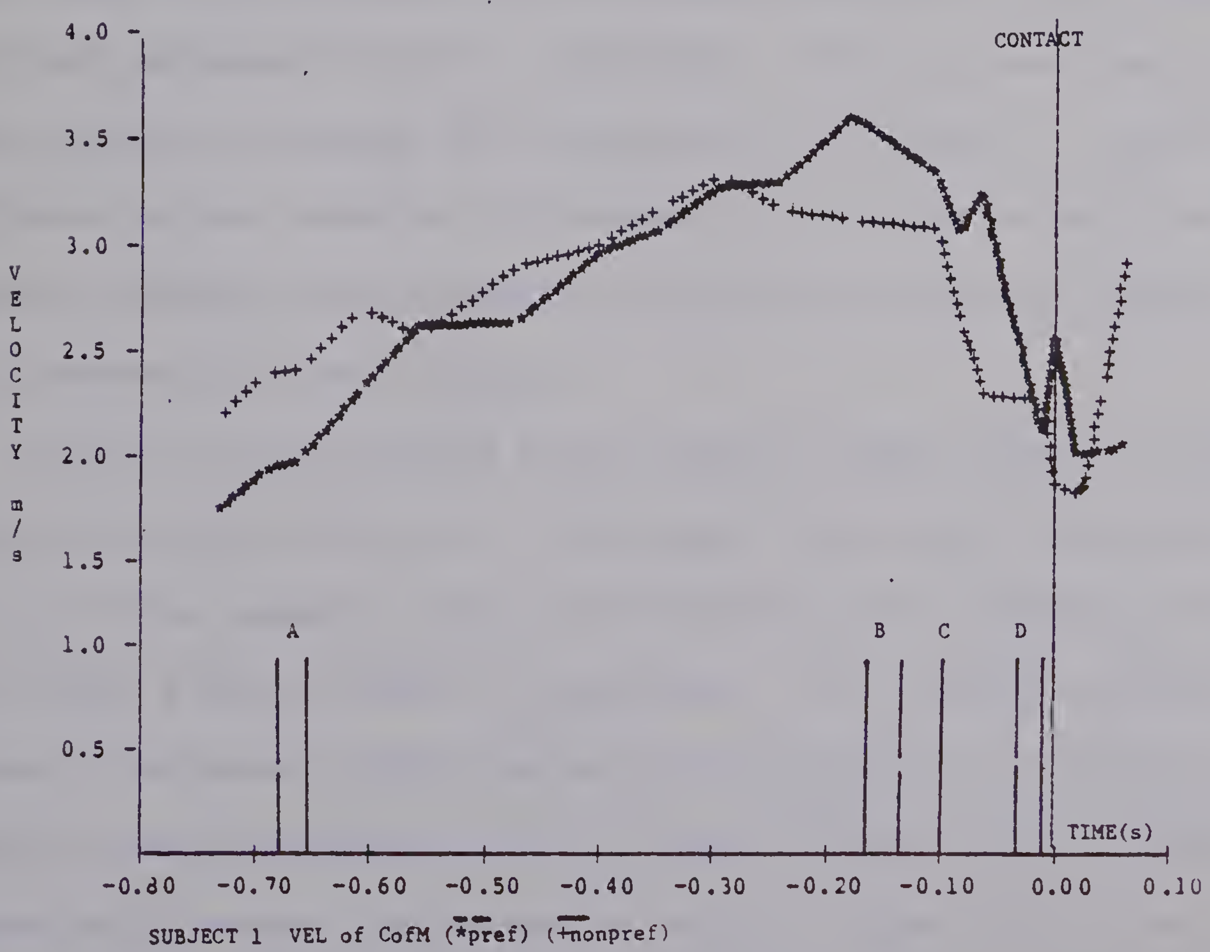


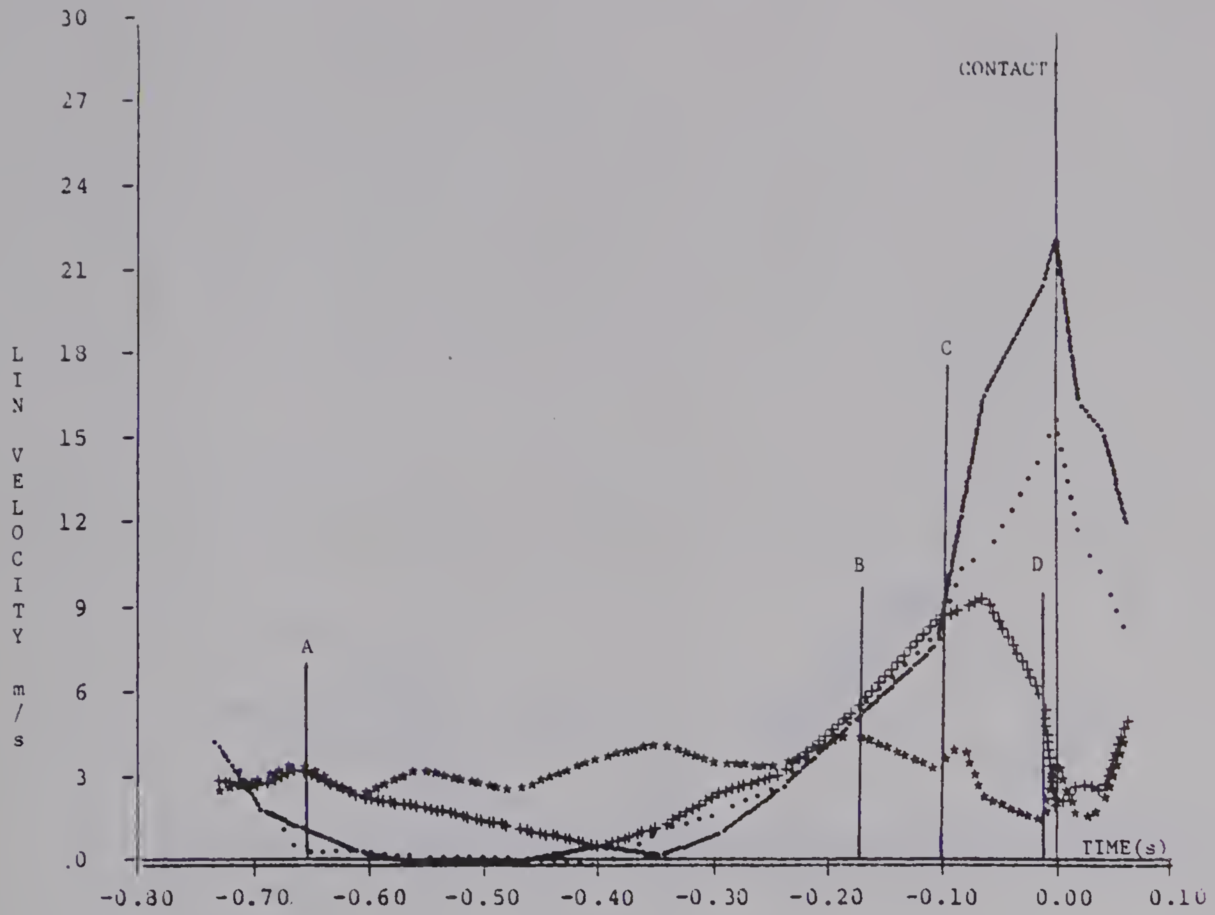
FIG. 15 VELOCITY OF C of M - SUBJECT 1 AND 4 NON PREF & PREF FOOT

Linear Velocity of Segmental End Points - Subjects 1 and 4

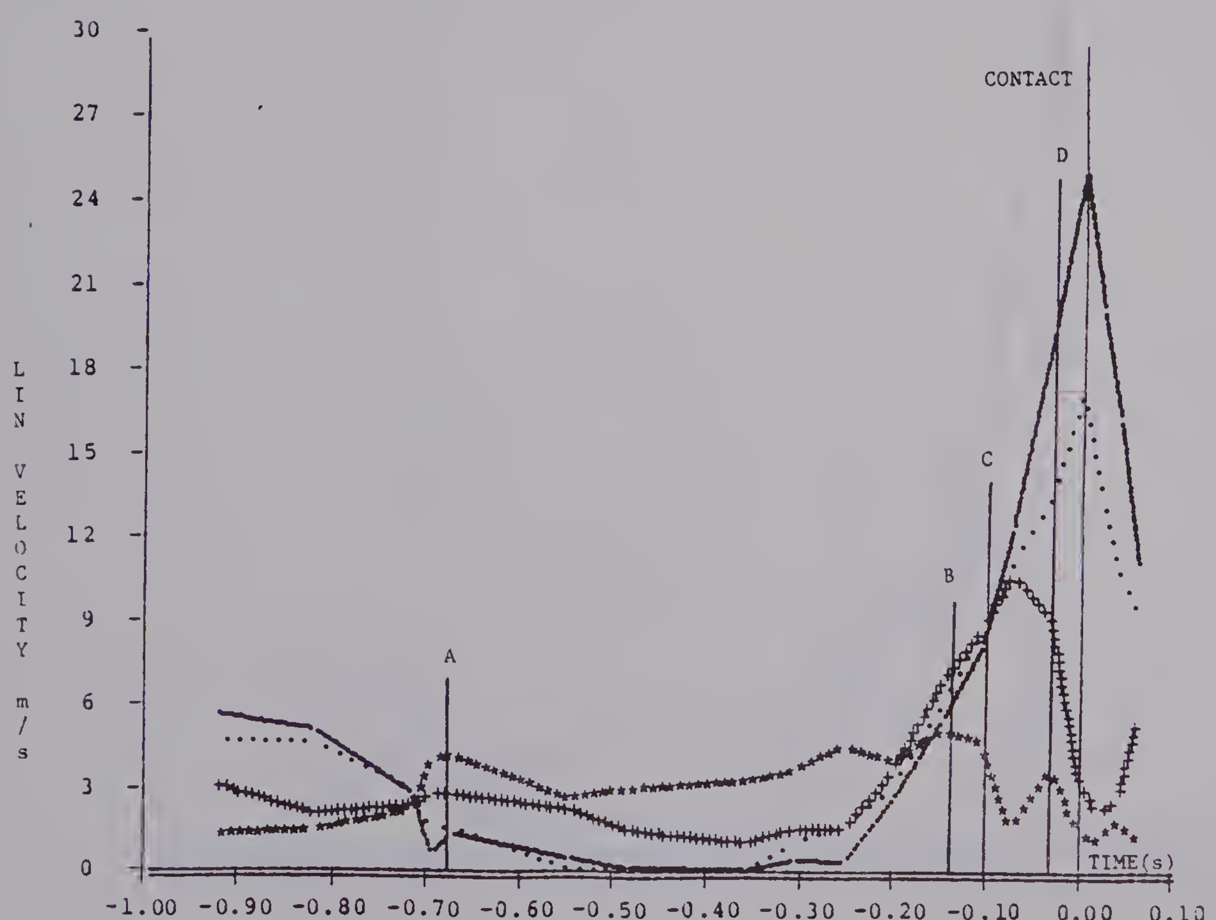
The linear velocities of the distal end points for the trunk, the thigh, the lower leg and the foot were measured in metres per second. Each segment was measured with reference to motion in the saggital plane around a transverse frontal axis. Subject 1 was classified as the superior kicker based on the kicking distances recorded (Table 3). The linear velocities of each of the segmental end points are shown in Figs. 16 and 17.

The changes in the linear velocities of each of the segments during the preferred and non preferred kicks for Subject 1 are very similar. The fluctuations in the velocity of the trunk, thigh, lower leg and foot are almost identical except for the non preferred foot, which records slightly lower maximum velocities for all segments. The trunk decreases after full leg flexion. Both the lower leg and foot continue to increase their velocity to ball contact. Both the preferred and non preferred side demonstrate the same sequence over slightly different time intervals. The foot and lower leg segments both decrease after ball contact.

Subject 4 was classified as the inferior kicker based on kicking distances recorded (Table 3). The changes in the linear velocities of each of the segments during the preferred and non preferred kicks for Subject 4 show a number of differences. The sequential fluctuations of the trunk, thigh, leg and foot are similar from kicking foot heel plant to support foot heel plant for both feet. The preferred thigh, however, maintains its velocity longer than the non preferred. Deceleration of the thigh is followed by increases in the adjoining lower leg and foot segments and maximum velocities are



SUBJECT 1 NON PREF (*trunk) (+knee)(..ankle) (-toe)



SUBJECT 1 PREF (*trunk) (+knee) (..ankle) (-toe)

A - KICKING FOOT HEEL PLANT B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION D - THIGH STOP

FIG. 16 LINEAR VELOCITY - SUBJECT 1 NON PREF & PREF FOOT

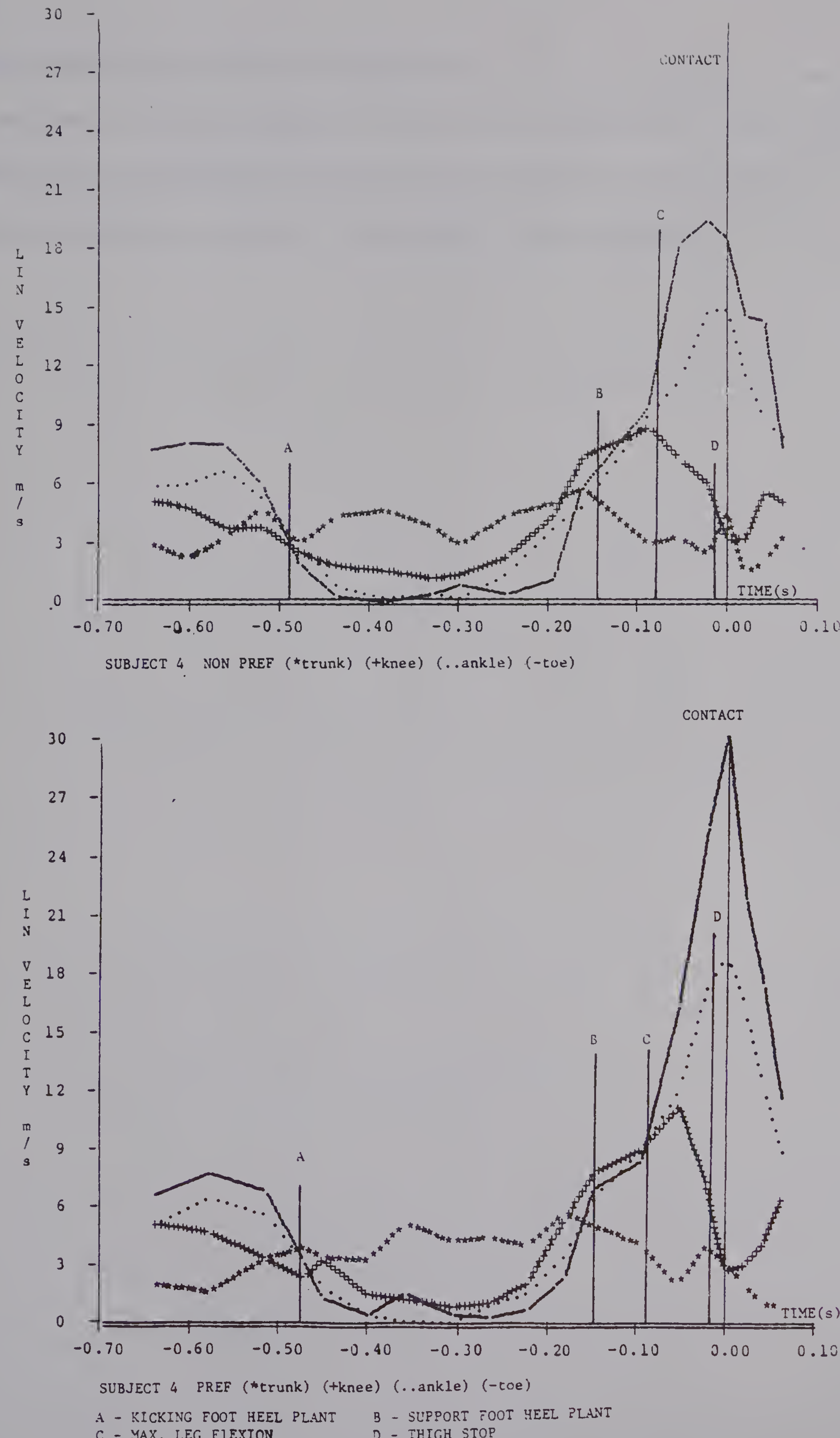


FIG. 17 LINEAR VELOCITY - SUBJECT 4 NON PREF AND PREF FOOT

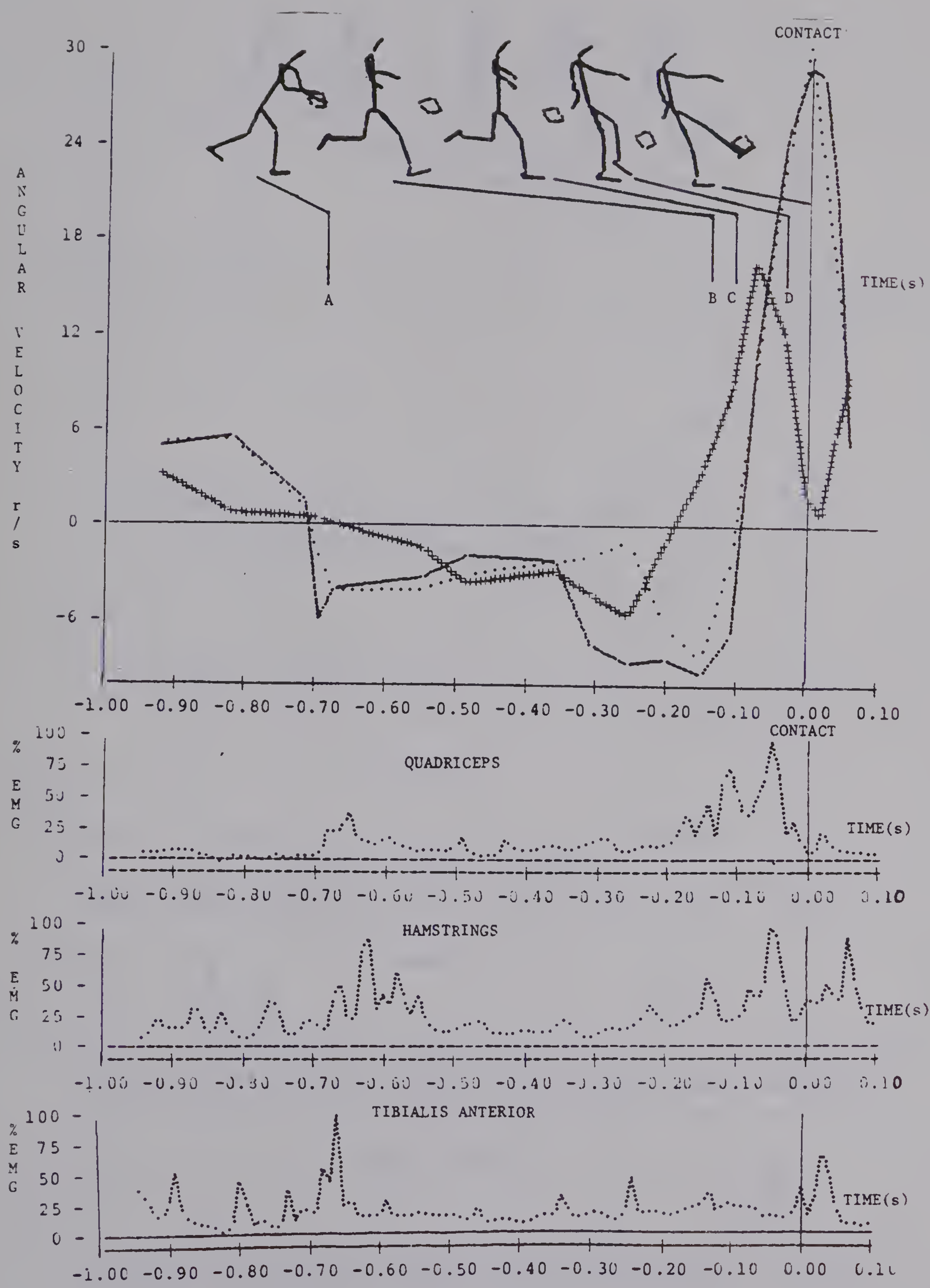
considerably higher for the preferred foot for all segments. The velocities of the leg and foot of the non preferred side level off then decrease immediately before contact with the ball, however, the preferred foot contact is at maximum linear velocity.

ELECTROMYOGRAPHY AND ANGULAR VELOCITY

Angular velocities were recorded in radians per second for the thigh, leg and foot of the preferred and non preferred kicking foot. Electromyographic (EMG) muscle action potentials for the Rectus Femoris (Quadriceps) the Biceps Femoris (Hamstrings) and Tibialis Anterior were recorded as a percentage of the maximum action potential for each muscle. The Rectus Femoris and the Biceps Femoris cross both the hip and knee joints and the Tibialis Anterior crosses the ankle joint. The electromyographic recordings are presented in graphical form over the same time period as the angular velocity for the thigh, leg and foot. The data is reported with reference to the kicking foot heel plant (KFHL), support foot heel plant (SFHL), full lower leg flexion (FL FLX) thigh flexion immediately before contact.(TFLX) and contact of foot and ball (CNT). The sequential variation in the angular velocities and electromyographic muscle action potentials is discussed with reference to:

1) the instant the kicking foot leaves the ground
2) the swing phase between kicking foot heel plant and support foot heel plant
3) the instant of support foot heel plant
4) the motion from support foot heel plant to leg and thigh flexion to contact with the ball

The subject data recorded in Table 2 was used to classify the six subjects into the most superior kicker using both feet and the most inferior performer with the non preferred foot. Angular velocity data and electromyographical data curves are presented for the non preferred foot of Subject 1 in Figs. 18 and 19. The Electromyography (EMG) activity is discussed in relation to the segments which the specific muscle controls. The Rectus Femoris is a two joint muscle



SUBJECT 1 PREF (+thigh) (..leg) (-foot)

A - KICKING FOOT HEEL PLANT
C - MAX. LEG FLEXION

B - SUPPORT FOOT HEEL PLANT
D - THIGH STOP

FIG. 18 ANGULAR VELOCITY AND ELECTROMYOGRAPHY - SUBJECT 1 PREFERRED FOOT

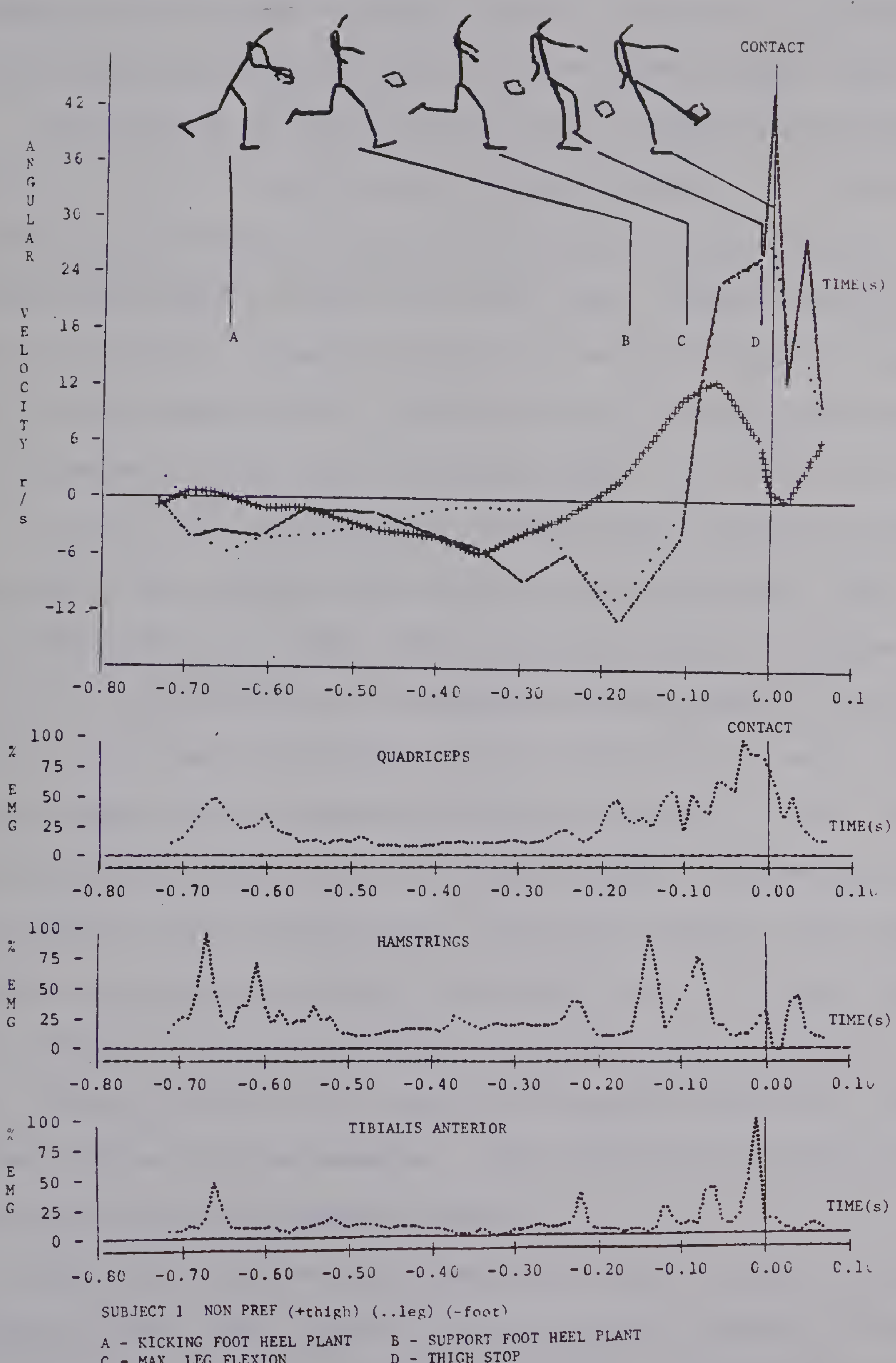


FIG. 19 ANGULAR VELOCITY AND ELECTROMYOGRAPHY - SUBJECT 1
NON PREFERRED FOOT

crossing both the hip and the knee and therefore is discussed in relation to the hip and leg angular velocity variations. The Tibialis crosses the ankle and is related to the foot segment angular velocities.

Rectus Femoris EMG activity for Subject 1 preferred and non preferred foot is particularly obvious during two phases. The first phase begins slightly before and beyond kicking foot heel plant and the second phase begins at support foot heel plant. The EMG activity of the Rectus Femoris increases to maximum percentage contraction levels at the forward knee position, remains high for the non preferred foot and decreases to contact for the preferred foot. The angular velocity of the hip for both legs indicates relatively low velocities at kicking foot heel plant, negative velocities during the swing phase, then increasing velocities before support foot heel plant up to maximum leg flexion. High velocities are decreasing from this point up to ball contact. Leg angular velocities for both legs follow a similar course to the thigh with the increase in velocity at support foot heel plant being initiated slightly after the thigh increase. Both preferred and non preferred legs increase sharply beyond thigh levels at full leg flexion and continue to maximum velocities at the point of ball contact. Foot velocities for both feet follow almost identical variations to the leg. The non preferred foot reaches higher maximum velocities, particularly the leg and foot segments. Thigh velocities are similar for both preferred and non preferred sides.

EMG activity for the Biceps Femoris for Subject 1 shows a similar pattern for both legs. High EMG levels are shown at kicking foot heel plant and again around support foot heel plant. High EMG levels are indicated at support foot heel plant, particularly on the non preferred

side. Levels drop just before ball contact and in both feet demonstrate activity after contact. Tibialis Anterior indicates fluctuating EMG activity but is more concentrated for the non preferred foot just before contact and for the preferred just after contact. Activity was relatively high at support foot heel plant for both feet.

The data indicates a definite relationship between thigh and leg angular velocities and EMG activity for both the Rectus Femoris and Biceps Femoris, particularly during angular velocity increase after support foot heel plant. There is an inconsistent relationship between Tibialis Anterior EMG and foot angular velocity.

Subject 4 angular velocities for both non preferred and preferred feet demonstrate very similar characteristics (Figs. 20 and 21). Maximum velocities for the thigh, leg and foot are slightly higher for the preferred feet and leg velocity increases begin slightly earlier at support foot heel plant. Sequential increases in thigh, leg and foot follow very similar patterns after support foot heel plant for both feet. The Rectus Femoris EMG activity shows two distinct activity areas for both feet. On kicking foot heel plant and after support foot heel plant to ball contact the quadriceps are noticeably active. Considerably higher activity immediately before contact is indicated on the non preferred side whereas the preferred side shows high EMG levels just before and at ball contact only. The Biceps Femoris fluctuates considerably and shows heavy activity after kicking foot heel plant and support foot heel plant of the non preferred foot. The preferred foot indicates a similar pattern, however activity levels are considerably lower. Tibialis Anterior EMG activity demonstrates fluctuating activity levels at a number of stages during the non

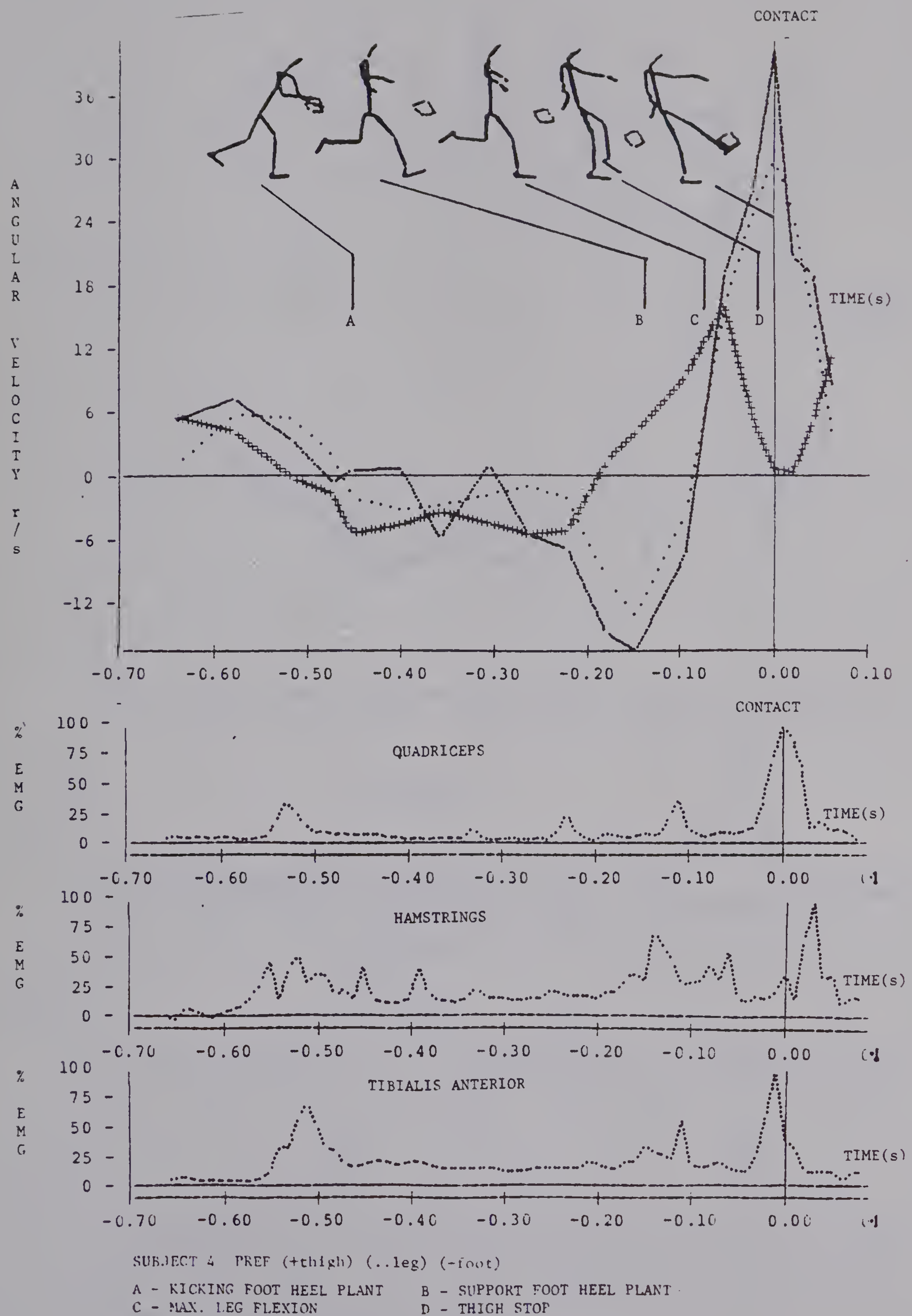
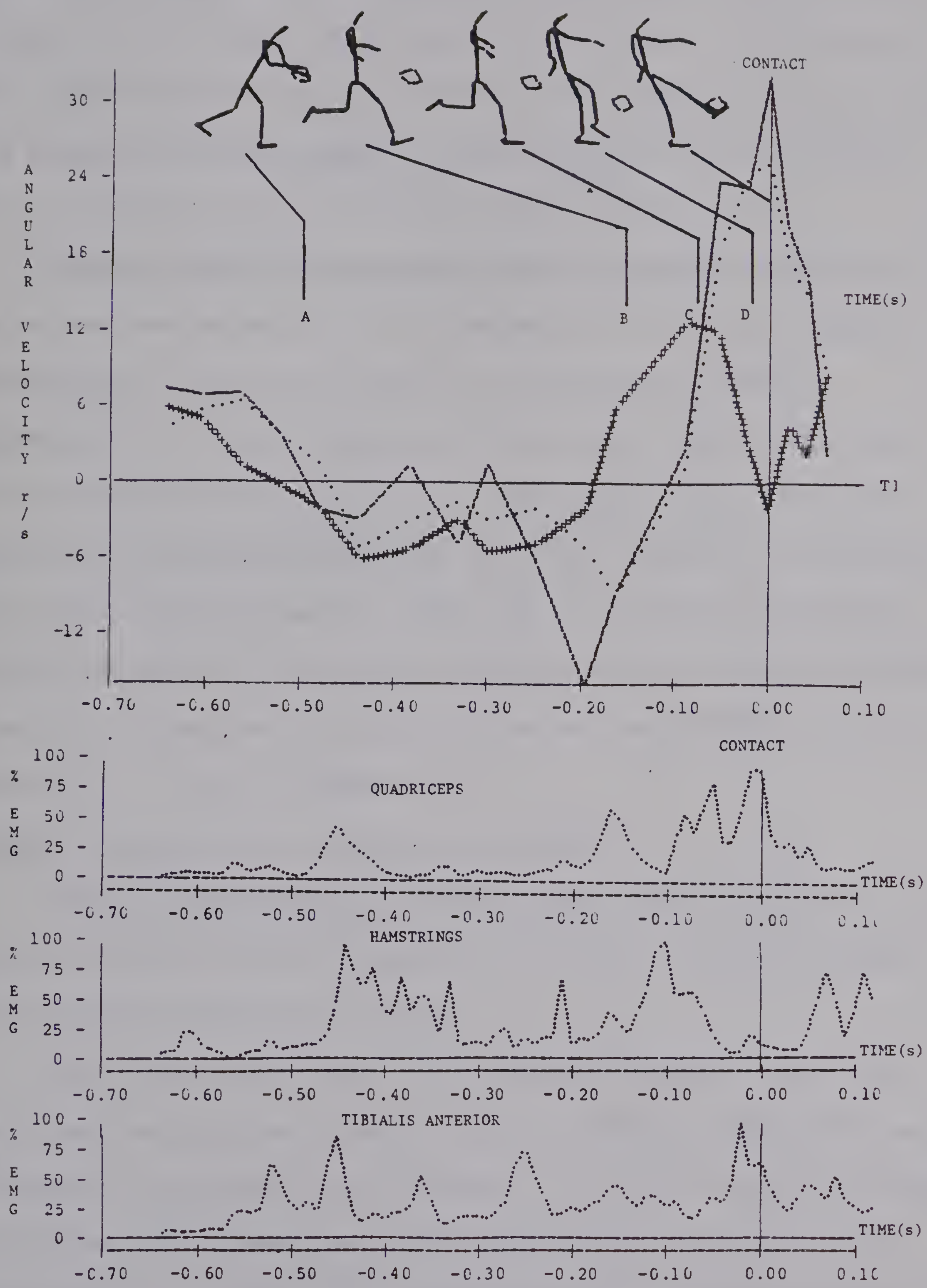


FIG. 20 ANGULAR VELOCITY AND ELECTROMYOGRAPHY - SUBJECT 4 PREFERRED FOOT



SUBJECT 4 NON PREF (+thigh) (..leg) (-foot)

A - KICKING FOOT HEEL PLANT B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION D - THIGH STOP

FIG. 21 ANGULAR VELOCITY AND ELECTROMYOGRAPHY - SUBJECT 4
NON PREFERRED FOOT

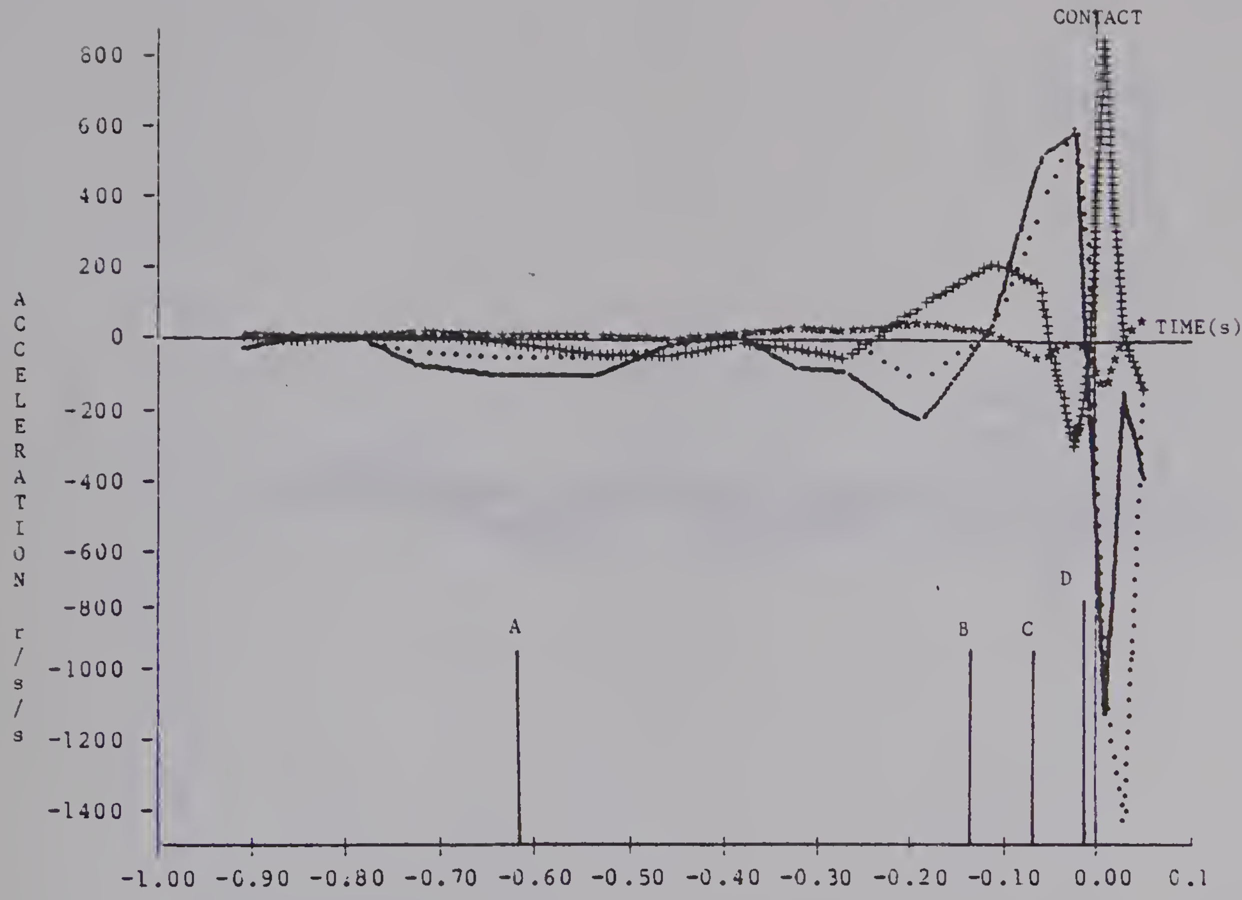
preferred kick, particularly during the swing phase mid way between kicking foot heel plant and support foot heel plant. The preferred foot shows Tibialis Anterior activity at the kicking foot heel plant and immediately before contact. The swing phase for the preferred foot is relatively free of Tibialis Anterior EMG activity.

Kinematic and Electromyographic data is presented for the preferred and non preferred foot for Subjects 0, 2, 3 and 5. Angular accelerations of the trunk, thigh, leg and foot are given in graphical form. Angular ranges of joint motion, linear velocities of the segmental end points for the trunk, thigh, leg and foot are presented in graphical form (Figs. 32 to 35). Raw data is presented for angular velocities of the thigh, leg, and foot and electromyographic recordings for the Rectus Femoris, Biceps Femoris and Tibialis Anterior are presented for the preferred and non preferred foot for Subjects 0, 2, 3 and 5 (Appendix E).

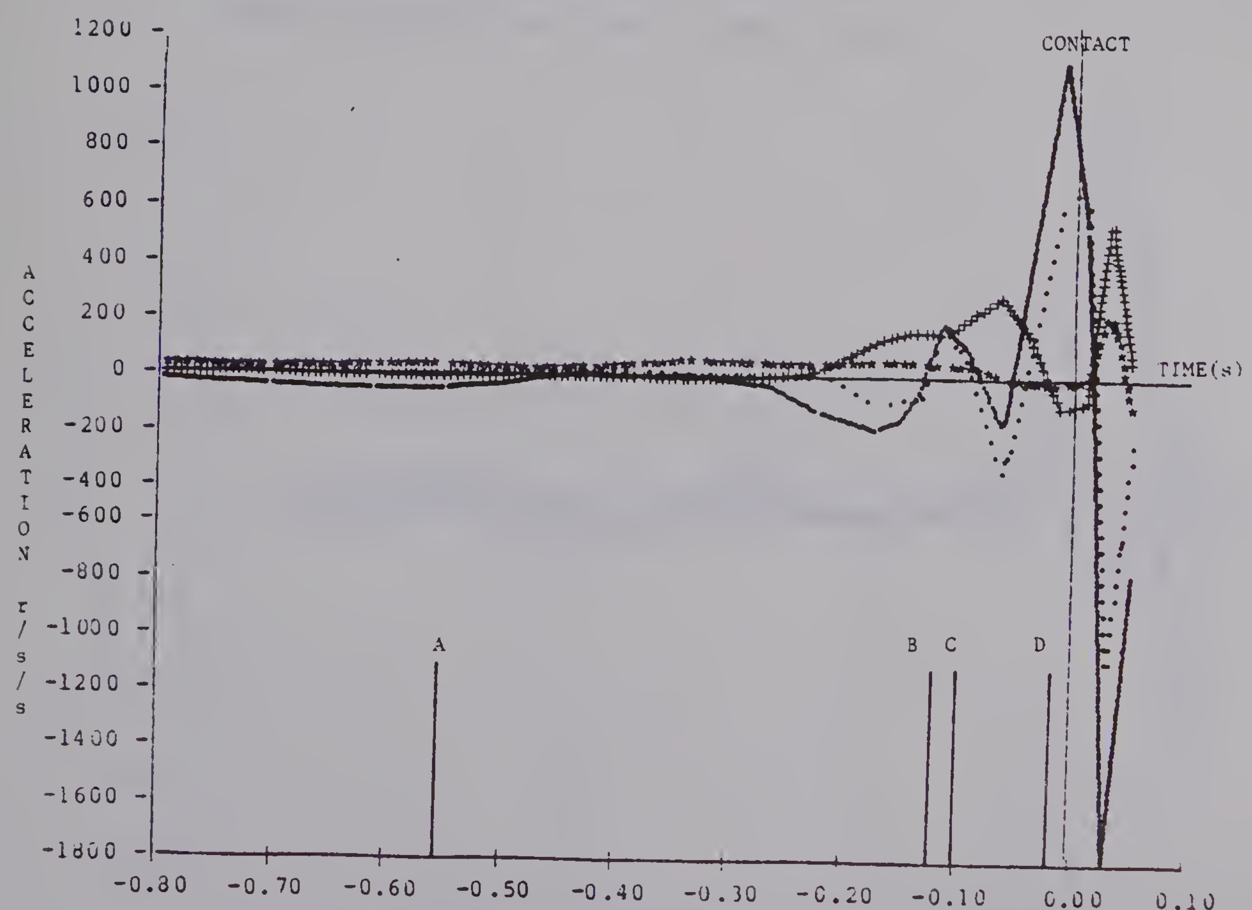
Angular Accelerations - Subjects 0, 2, 3 and 5

Angular acceleration data for the trunk, thigh, leg and foot of the non preferred feet of Subjects 0, 2, 3 and 5 show very similar characteristics (Figs. 22 to 25).

Thigh accelerations peak in all subjects between support foot heel plant and full knee flexion. As the thigh decelerates the leg continues to accelerate on all subjects. Peak leg accelerations occur just before the forward knee position and in all cases the leg is decelerating at contact. Foot accelerations for the non preferred feet of Subjects 0, 2, 3 and 5 all increase at greater rates and slightly before the leg begins to accelerate. The foot is decelerating before and up to contact in all subjects.



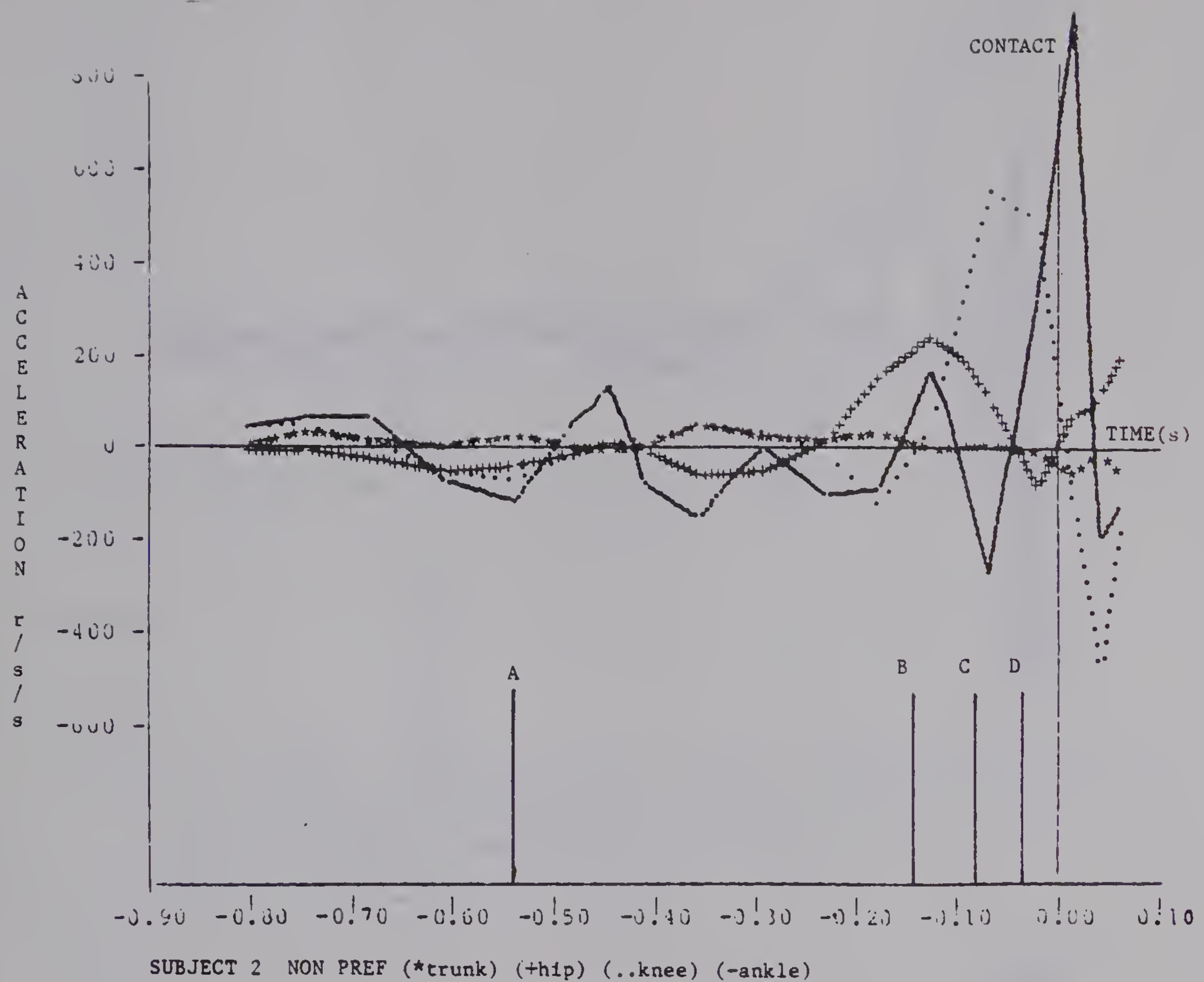
SUBJECT 0 NON PREF (*trunk) (+hip) (..knee) (-ankle)



SUBJECT 0 PREF (*trunk) (+hip) (..knee) (-ankle)

A - KICKING FOOT HEEL PLANT B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION D - THIGH STOP

FIG. 22 ANGULAR ACCELERATIONS - SUBJECT 0 NON PREF & PREF FOOT



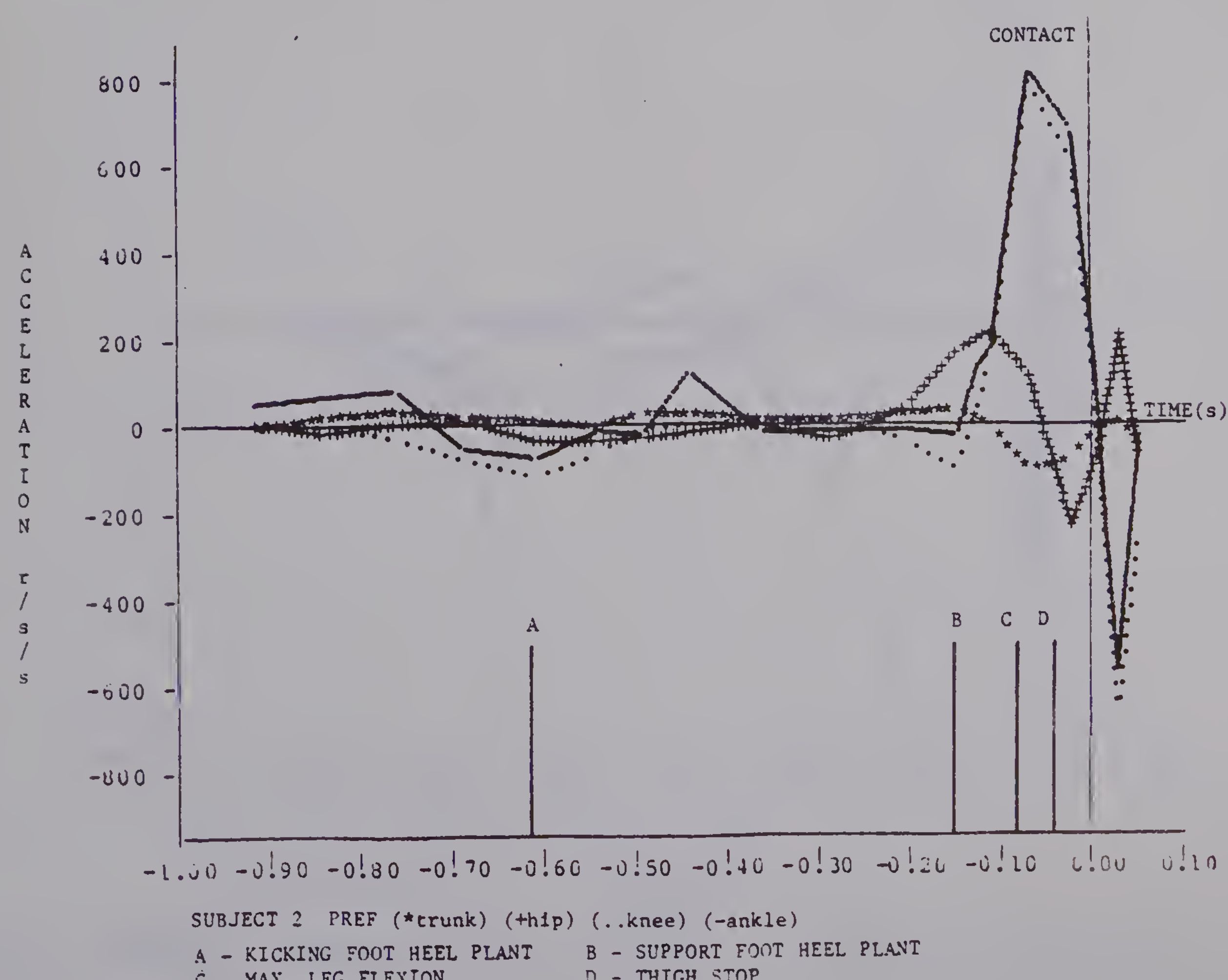


FIG. 23 ANGULAR ACCELERATIONS - SUBJECT 2 NON PREF & PREF FOOT

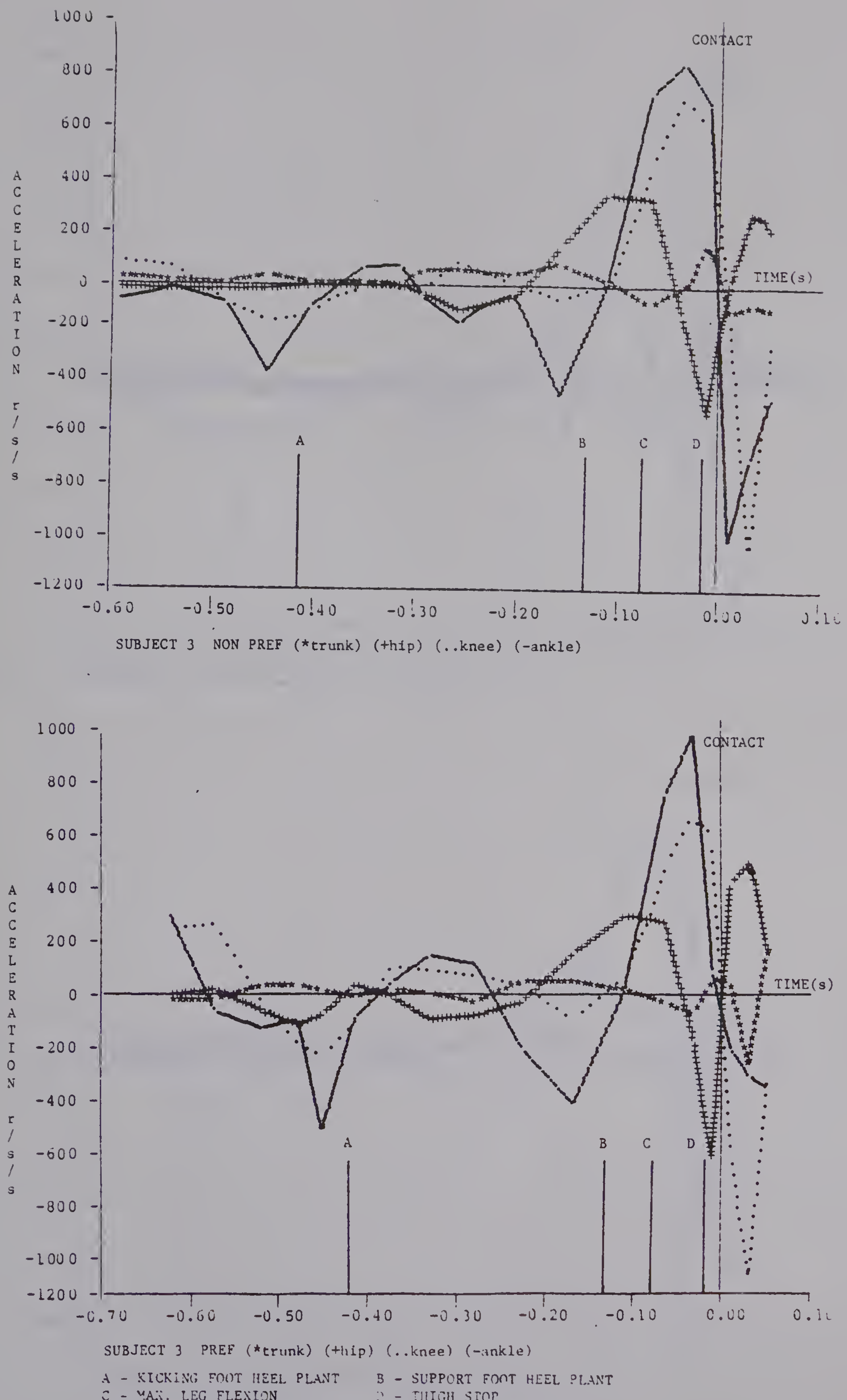
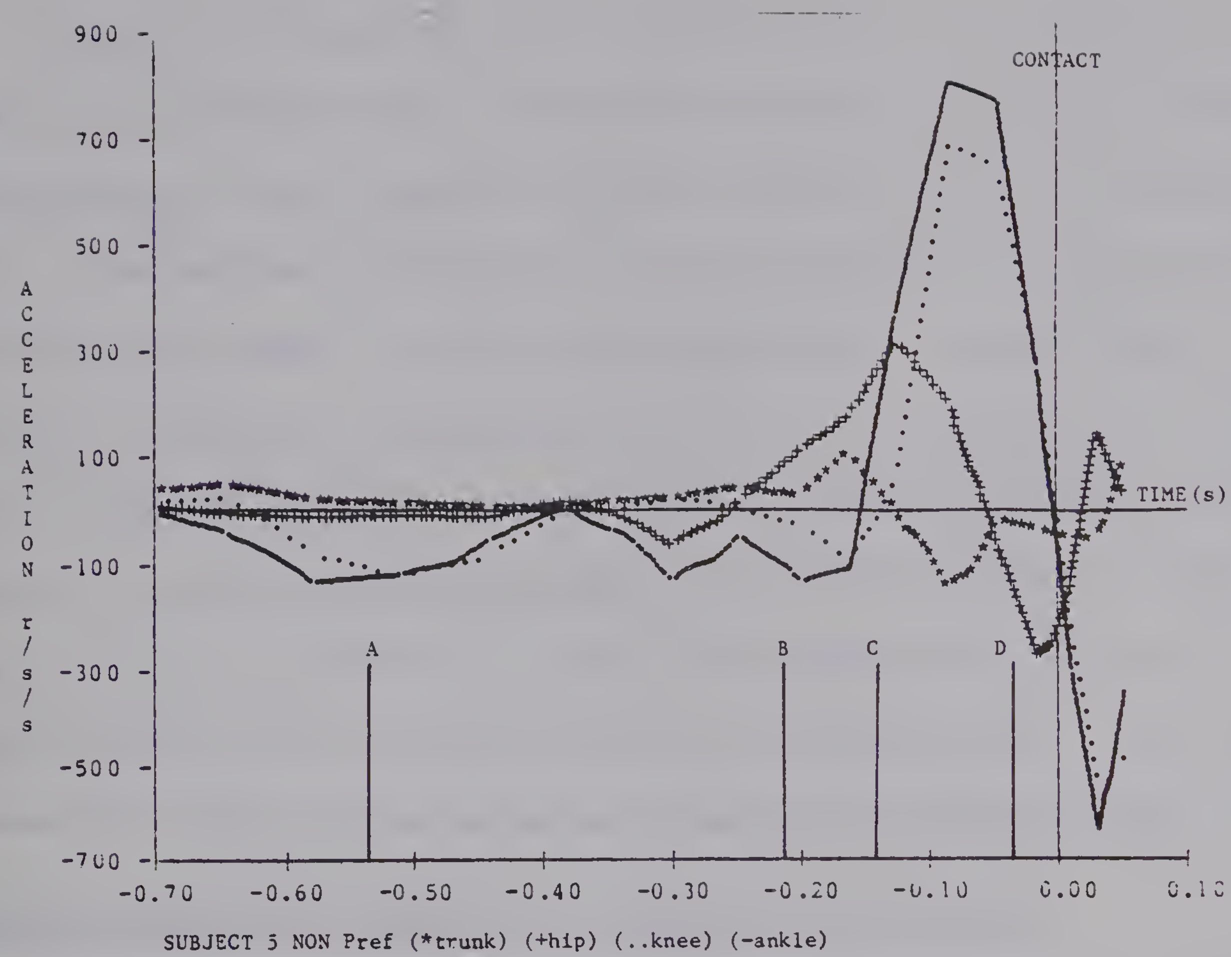


FIG.24 ANGULAR ACCELERATIONS - SUBJECT 3 NON PREF & PREF FOOT



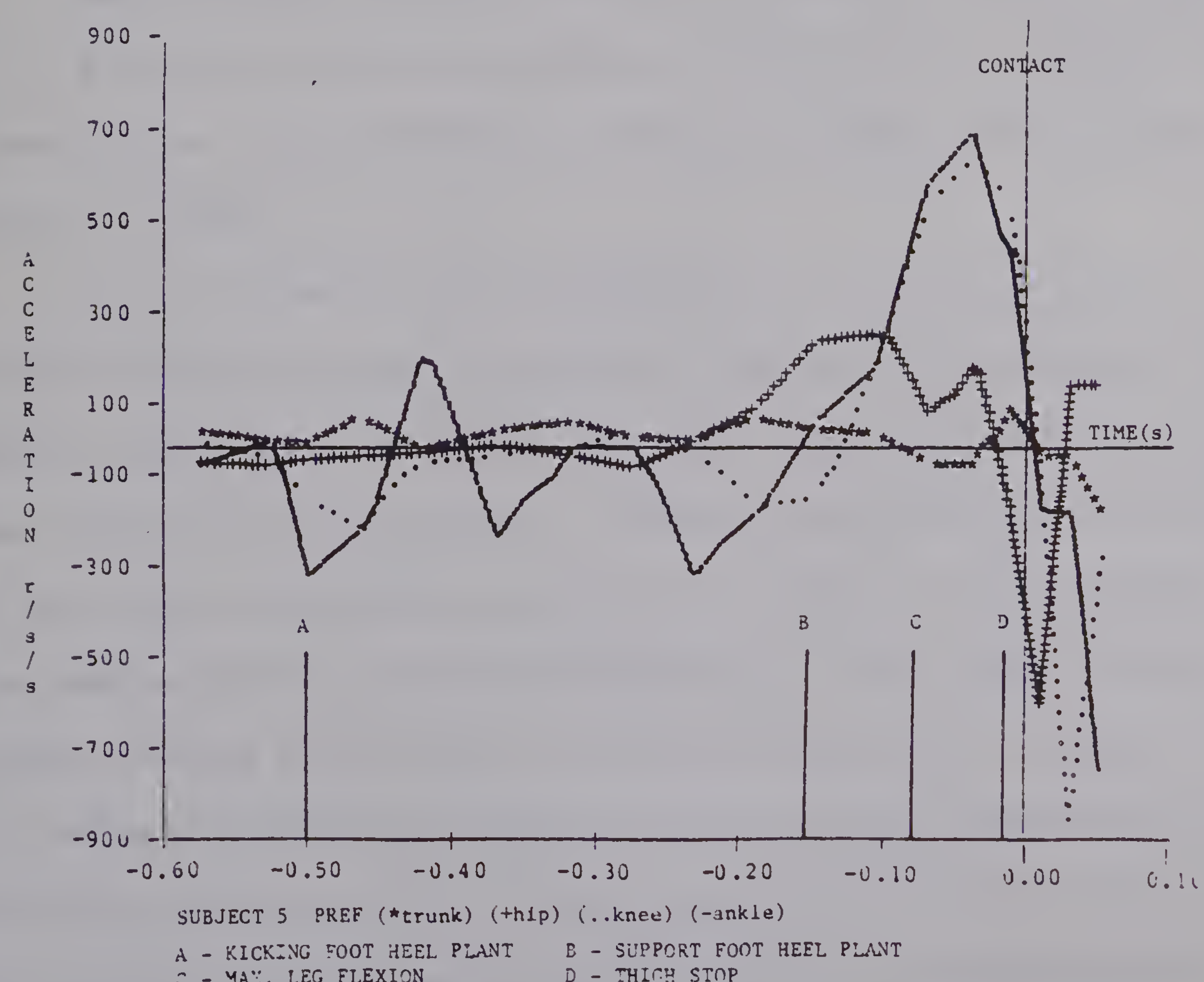


FIG. 25 ANGULAR ACCELERATIONS - SUBJECT 5 NON PREF & PREF FOOT

Angular accelerations for the preferred foot for Subjects 0, 2, 3 and 5 all indicate similar acceleration variations and in all cases the fluctuation of each segment is closely related to the non preferred foot. The maximum accelerations of all the segments are greater in the preferred feet than it is in the non preferred. The joint which indicates the greatest variation is the foot. Acceleration and deceleration levels of the foot are most obvious between the kicking foot and support foot heel plants particularly in Subjects 3 and 5. During the approach phases of Subject 0, few of the segment accelerations show great variation for both preferred and non preferred feet. Both feet demonstrate very similar patterns throughout the entire kicking cycle.

Angular Ranges of Joint Motion - Subjects 0, 2, 3 and 5

Angular ranges of motion are given in graphical form for Subjects 0, 2, 3 and 5 for the non preferred and preferred foot. Ranges are given for the trunk and thigh at the hip, the knee, and the ankle (Figs. 26 to 29).

The non preferred feet of Subjects 0, 2, 3 and 5 show very similar characteristics. The maximum range for hip extension is just before support foot heel plant and occurs immediately before maximum knee extension in all subjects. Maximum knee flexion and the extension of the thigh after support foot heel plant occurs at approximately the same moment for all non preferred feet. Ankle motion follows a similar pattern in all the non preferred kicks for each subject. In all subjects the foot is extended during full knee flexion and up to the forward thigh position. During contact the foot is flexing at the ankle in all subjects, particularly Subject 2. The preferred foot kicks for Subjects 0, 2, 3 and 5 all show similar joint range

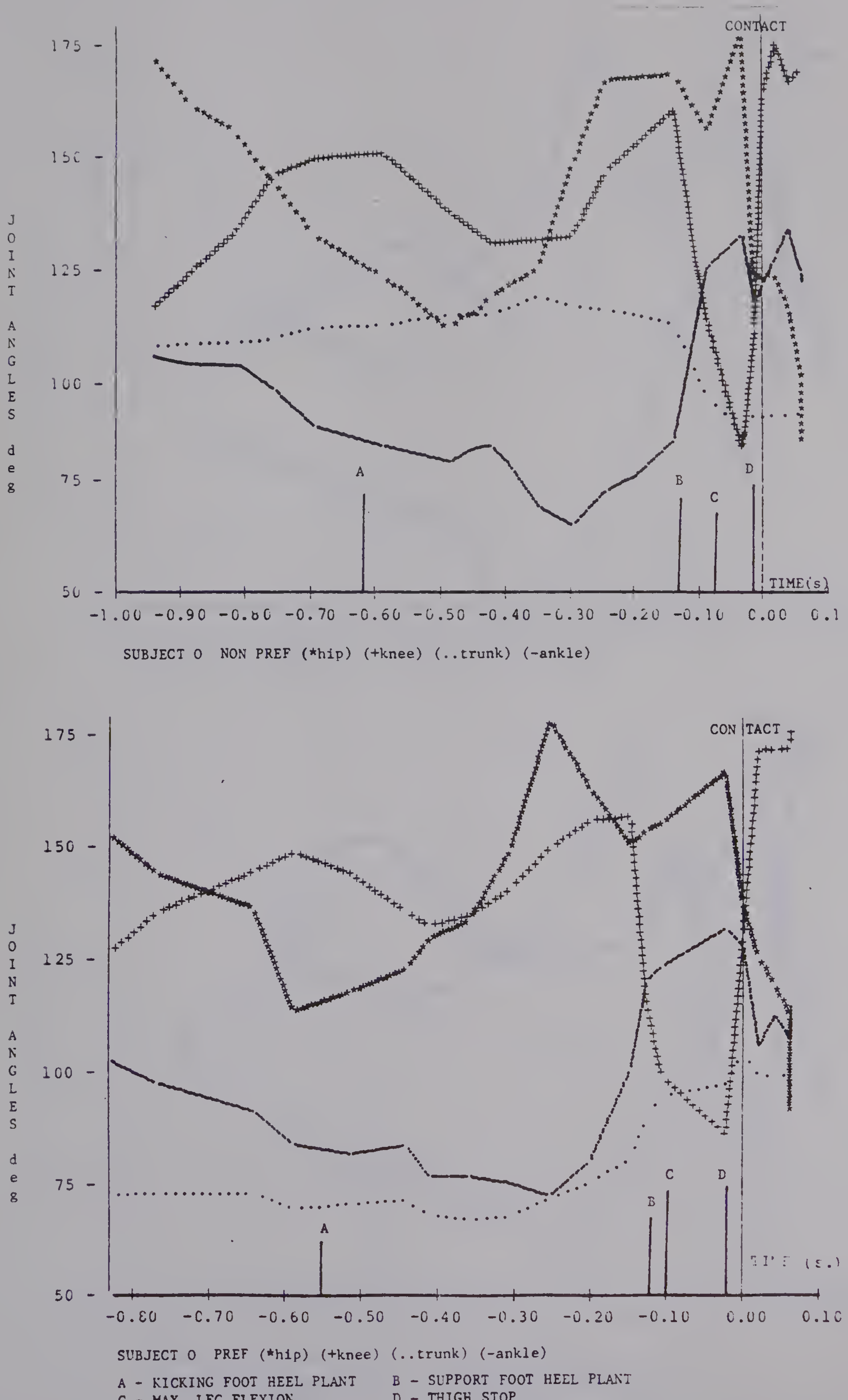
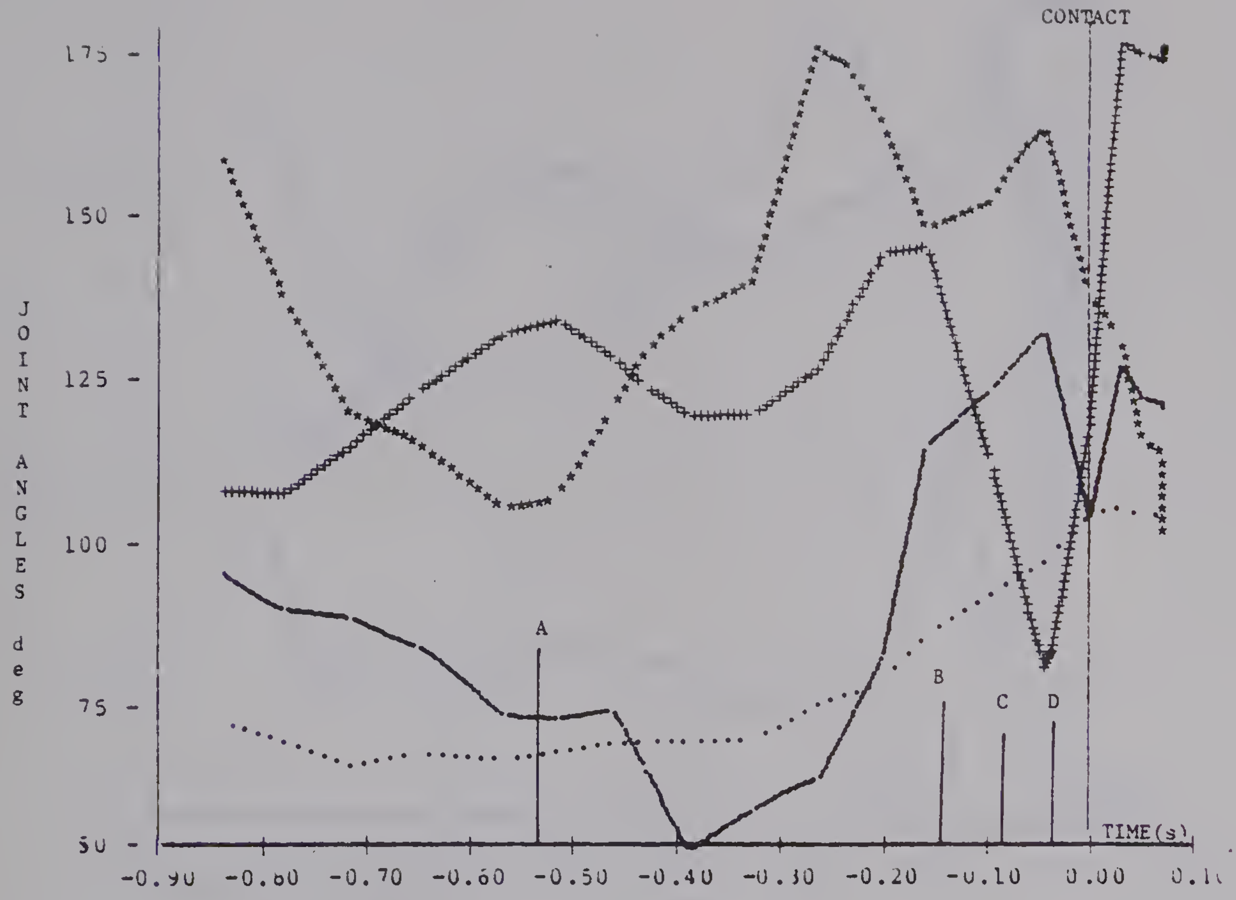
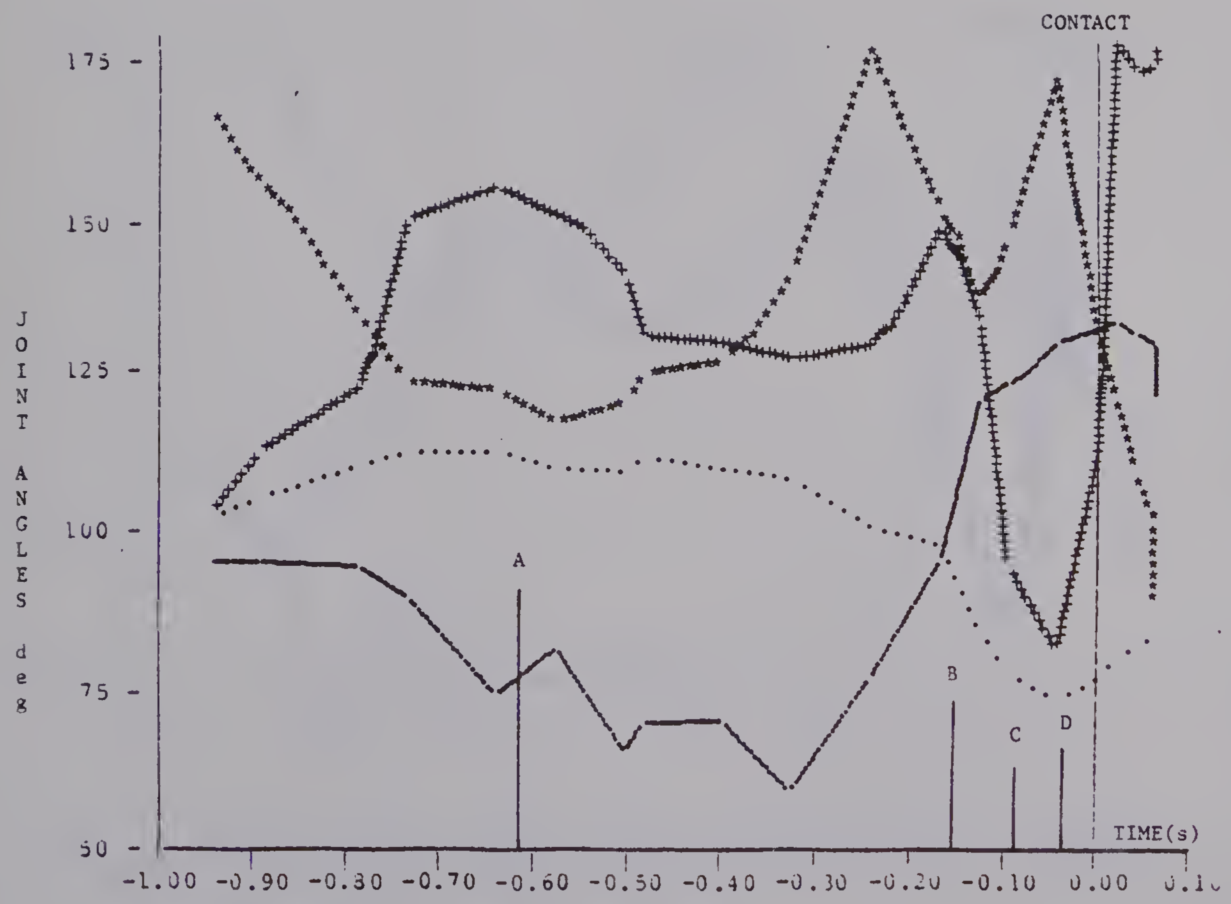


FIG. 26 JOINT ANGLE RANGES - SUBJECT O NON PREF & PREF FOOT



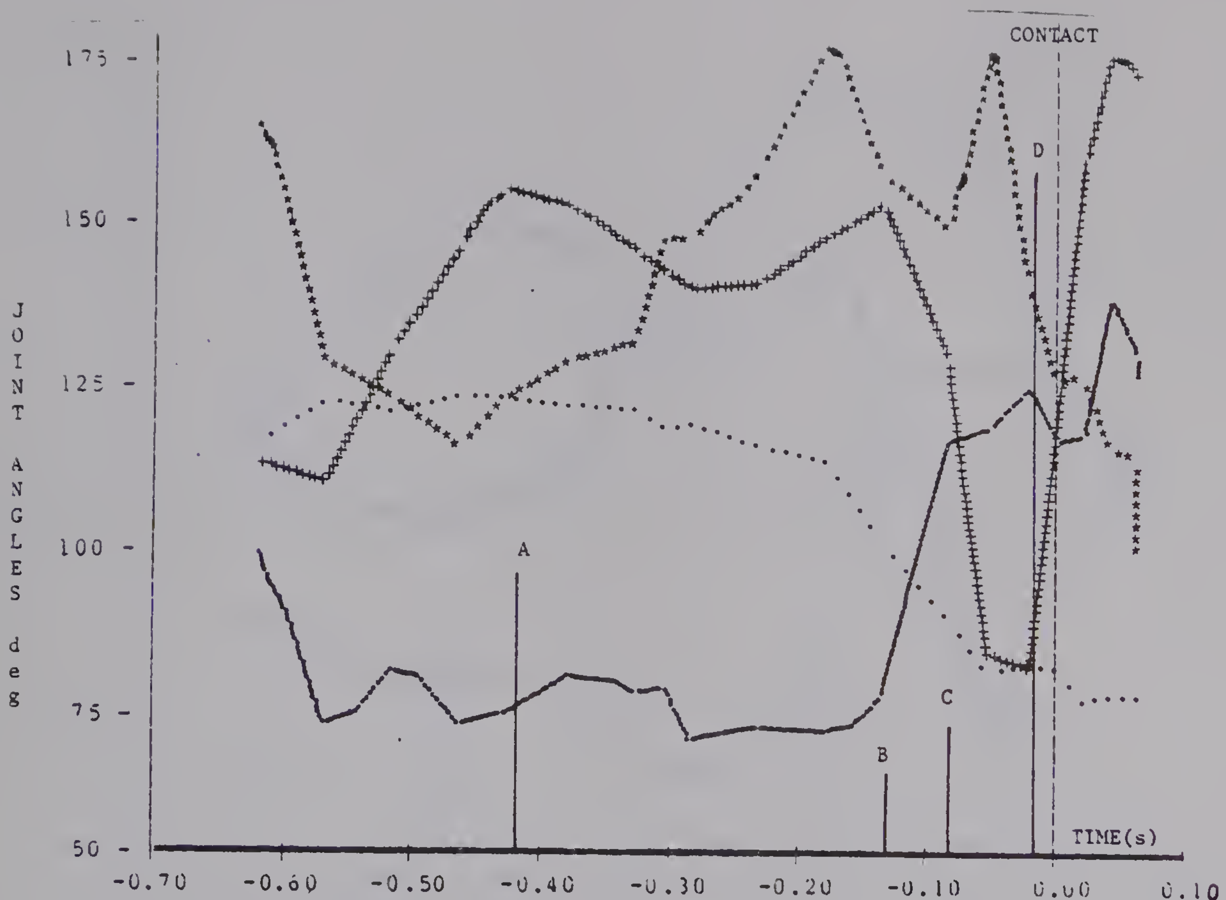
SUBJECT 2 NON PREF (*hip) (+knee) (..trunk) (-ankle)



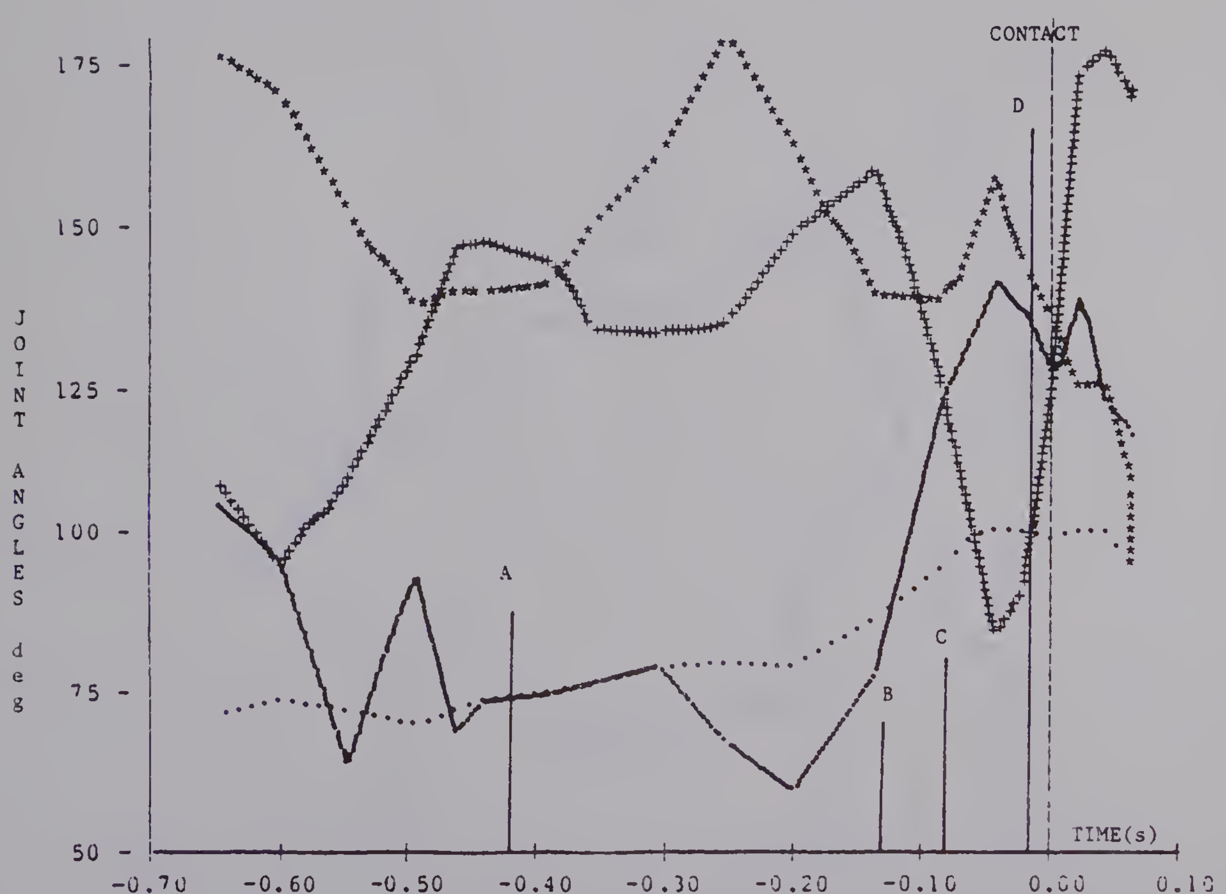
SUBJECT 2 PREF (*hip) (+knee) (..trunk) (-ankle)

A - KICKING FOOT HEEL PLANT B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION D - THIGH STOP

FIG. 27 JOINT ANGLE RANGES - SUBJECT 2 NON PREF & PREF FOOT



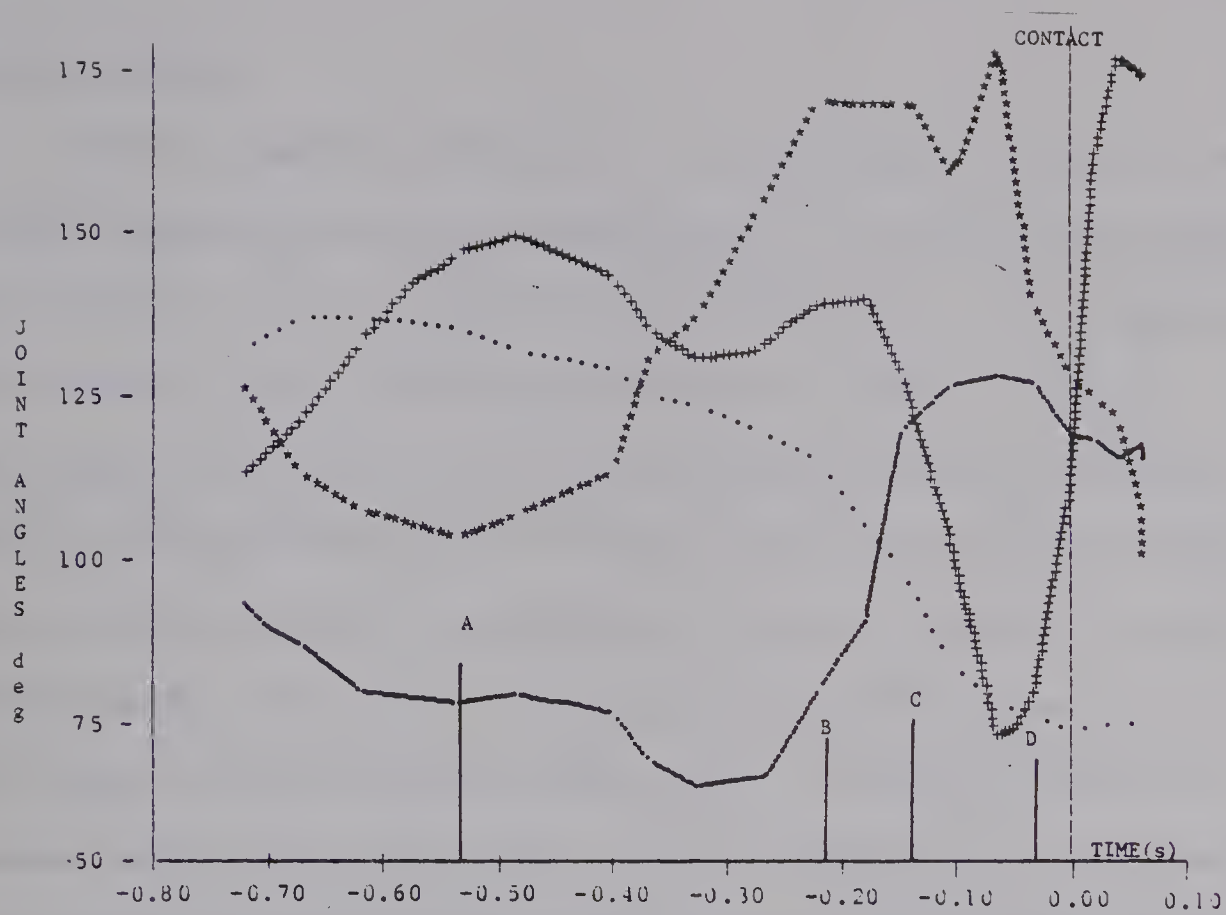
SUBJECT 3 NON PREF (*hip) (+knee) (..trunk) (-ankle)



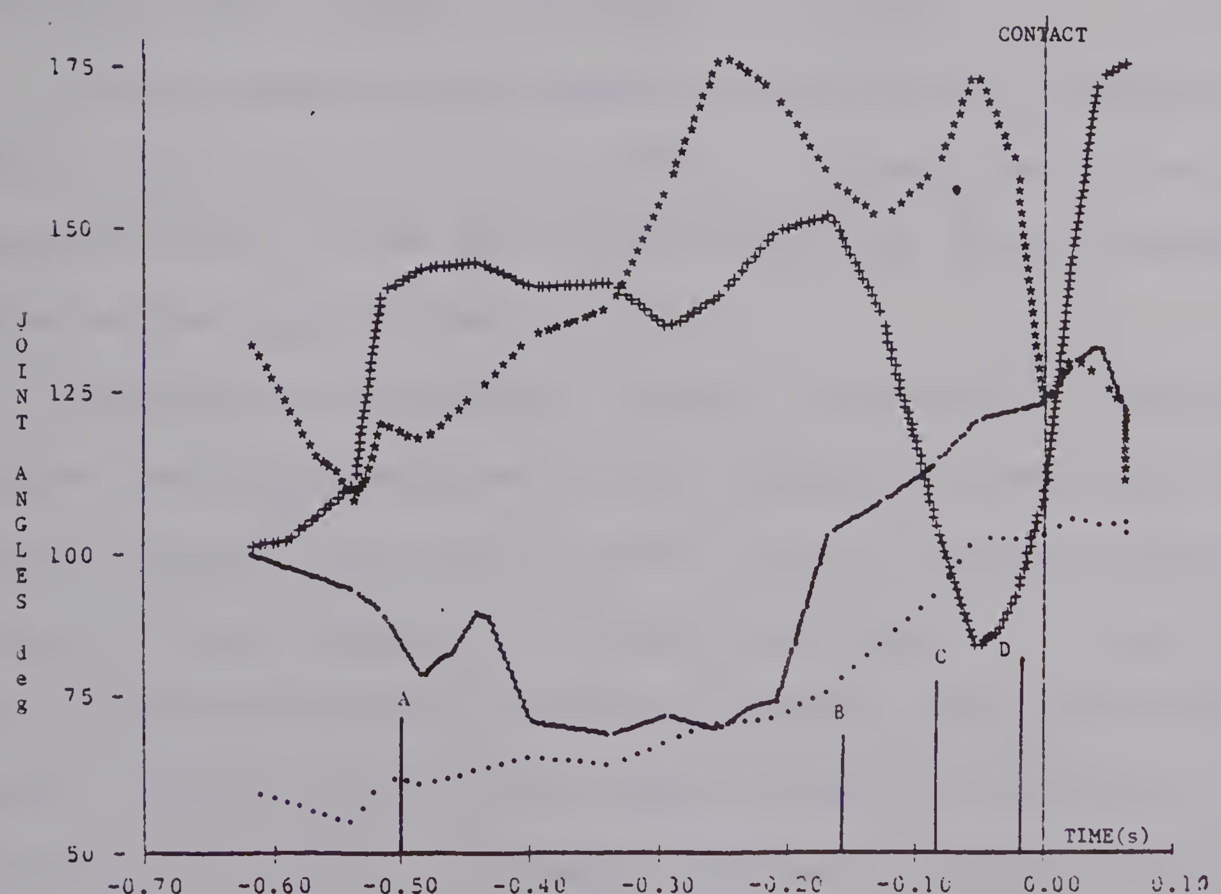
SUBJECT 3 PREF (*hip) (+knee) (..trunk) (-ankle)

A - KICKING FOOT HEEL PLANT B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION D - THIGH STOP

FIG. 28 JOINT ANGLE RANGES - SUBJECT 3 NON PREF & PREF FOOT



SUBJECT 5 NON PREF (*hip) (+knee) (..trunk) (-ankle)



SUBJECT 5 PREF (*hip) (+knee) (..trunk) (-ankle)

A - KICKING FOOT HEEL PLANT　　B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION　　D - THIGH STOP

FIG. 29 JOINT ANGLE RANGES - SUBJECT 5 NON PREF & PREF FOOT

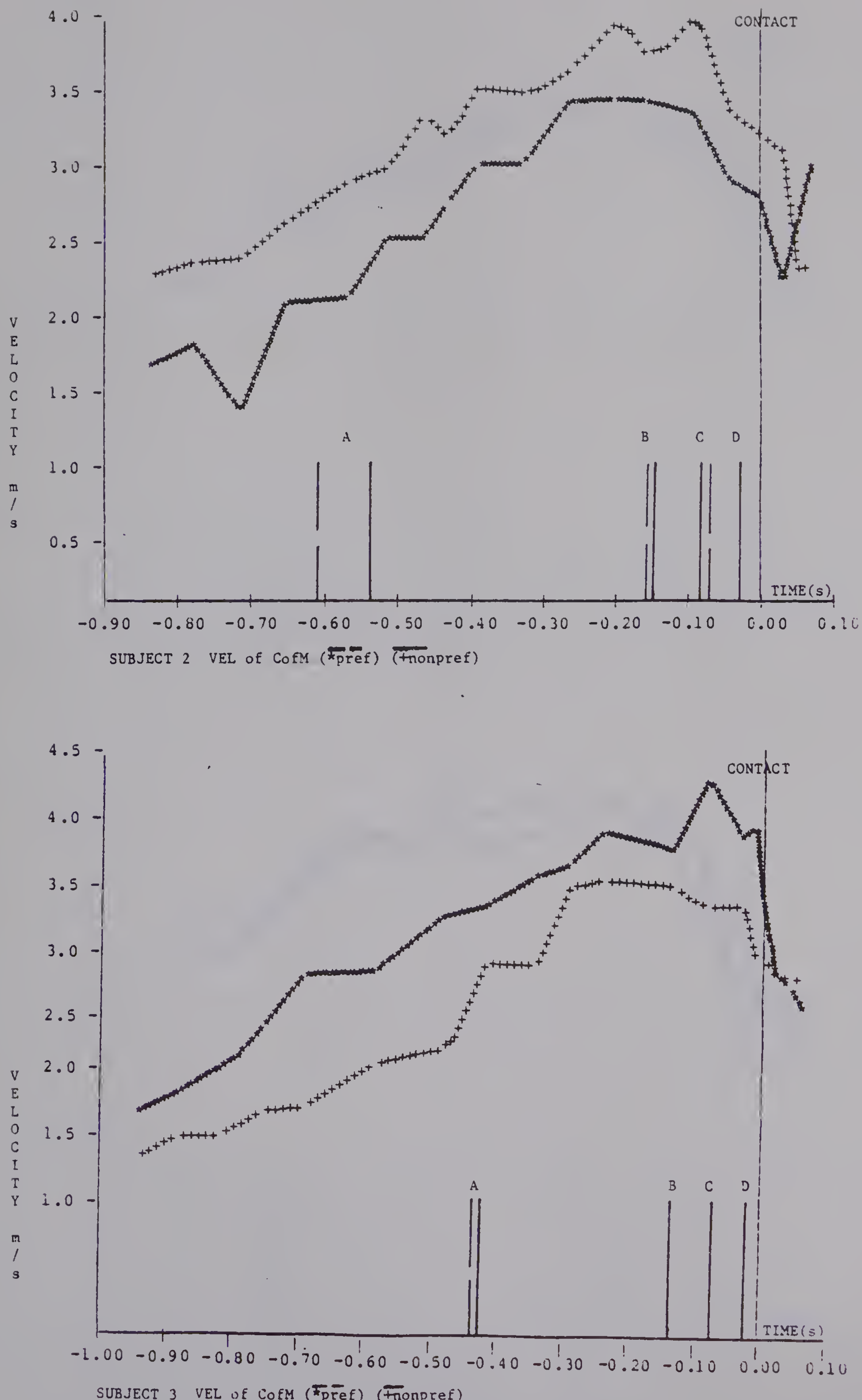
characteristics.

The hip ranges for Subjects 0, 2, 3 and 5 are very similar and closely approximate the non preferred feet. The knee joint ranges are all equal to or greater than the non preferred feet. Knee flexion and hip extension occur at the same time for all subjects. Ankle variations are similar for all the preferred feet and approximate the non preferred kicks except for the final stage from full flexed thigh positions when all but Subject 3 continue to extend the ankle through impact with the ball. Trunk angles gradually increase for all subjects on the preferred kicks except for Subject 2 which decreases after support foot plant. The data indicates no consistency with trunk angle variations between preferred and non preferred kicks.

Velocity of Centre of Mass - Subjects 0, 2, 3 and 5

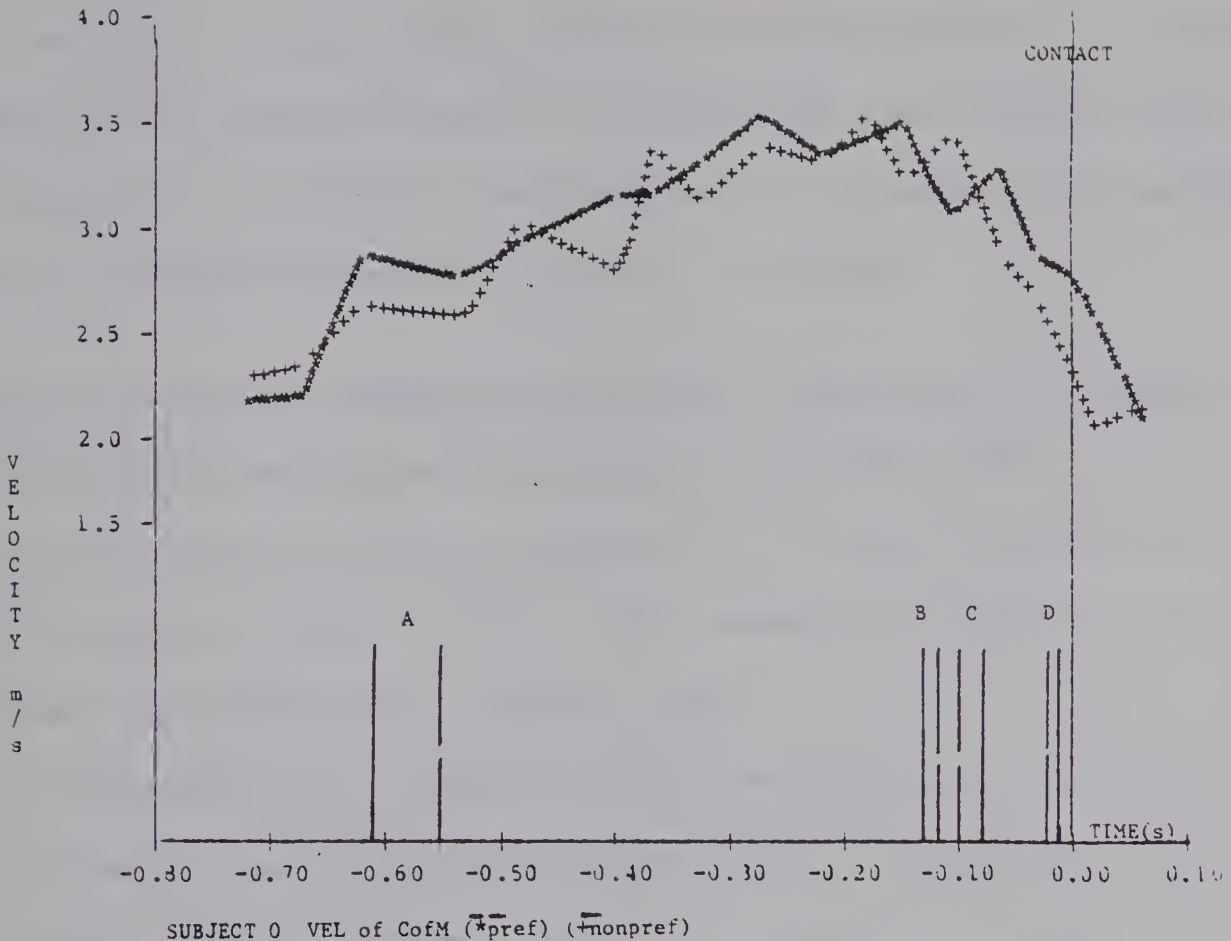
Centre of Mass velocity changes for Subjects 0, 2, 3 and 5 are shown in Figs. 30 and 31. Velocities are measured in metres per second and data is shown based on MIT scales (Fig. 10) and segmental motion in the saggital plane.

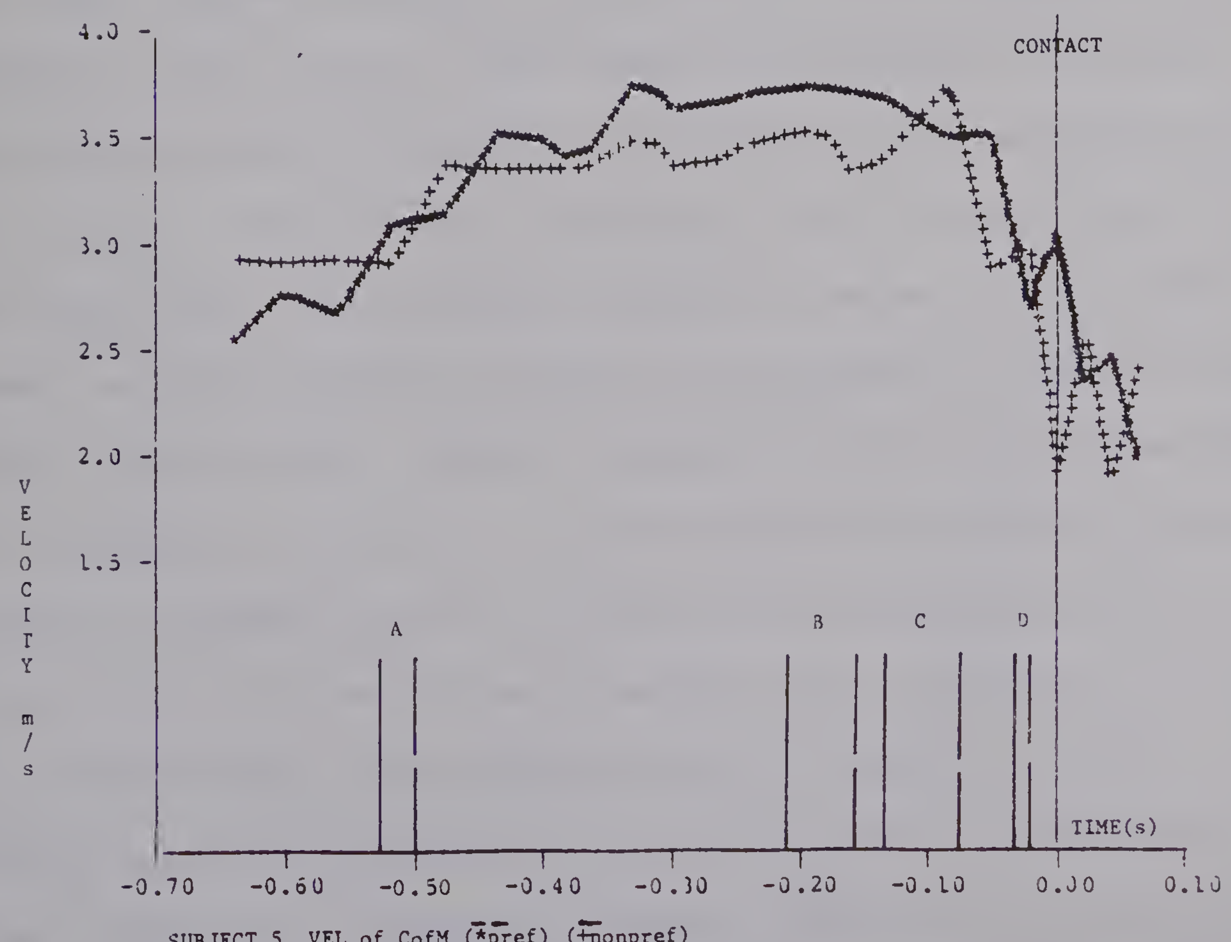
All subjects show a gradual increase in the velocity of the centre of mass from kicking foot heel plant to support foot heel plant. From support foot heel plant to ball contact there is a general decrease in velocity. In all subjects but Subject 2 the preferred foot centre of mass velocities maintain higher levels throughout the entire kicking motion. Velocities peak for all subjects when the kicking leg is close to full flexion. The greatest fluctuations are indicated by the non preferred foot of Subject 0 between kicking foot and support foot heel plant, however the velocities become constant after maximum levels are reached at full leg flexion.



A - KICKING FOOT HEEL PLANT B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION D - THIGH STOP

FIG. 30 VELOCITY OF CENTRE OF MASS - SUBJECTS 2 AND 3
NON PREF & PREF FOOT





A - KICKING FOOT HEEL PLANT B - SUPPORT FOOT HEEL PLANT
C - MAX. LEG FLEXION D - THIGH STOP

FIG. 31 VELOCITY OF CENTRE OF MASS - SUBJECTS 0 AND 5
NON PREF & PREF FOOT

The data did not indicate great differences between the velocity changes in the centre of mass for preferred and non preferred kicks in Subjects 0, 2, 3 and 5. The preferred foot, however, does maintain higher velocities throughout except for one subject.

Linear Velocities at Segmental End Points - Subjects 0, 2, 3 and 5

The linear velocities of the distal end points of the trunk, thigh, lower leg and foot for Subjects 0, 2, 3 and 5 are shown in graphical form in Figs. 32 to 35. Each segment was measured with reference to motion in the saggital plane.

The changes in the segmental linear velocities for the non preferred feet of each of the four subjects (0, 2, 3 and 5) are very consistent with one another. Trunk variations peak at support foot heel plant, decrease slightly at the full forward thigh position, then increase to ball cóntact. Thigh velocities increase as the trunk decreases and maximum velocities are reached at full knee flexion for all subjects. The thigh then decelerates to ball contact for all non preferred kicks. Leg velocities continue to increase as the thigh segment velocity decreases and peak leg velocities are reached on foot contact with the ball. The foot segments for all non preferred feet are increasing in velocity at the same rate as the thigh and leg but continue to maximum levels at a greater rate than the leg. Ball contact occurs at a very close to maximum foot acceleration in all non preferred kicks. The preferred kicks for each subject show identical characteristics to the non preferred feet for segmental linear velocities. The maximum segmental velocities for each preferred kick are greater than the maximum velocities of the non preferred

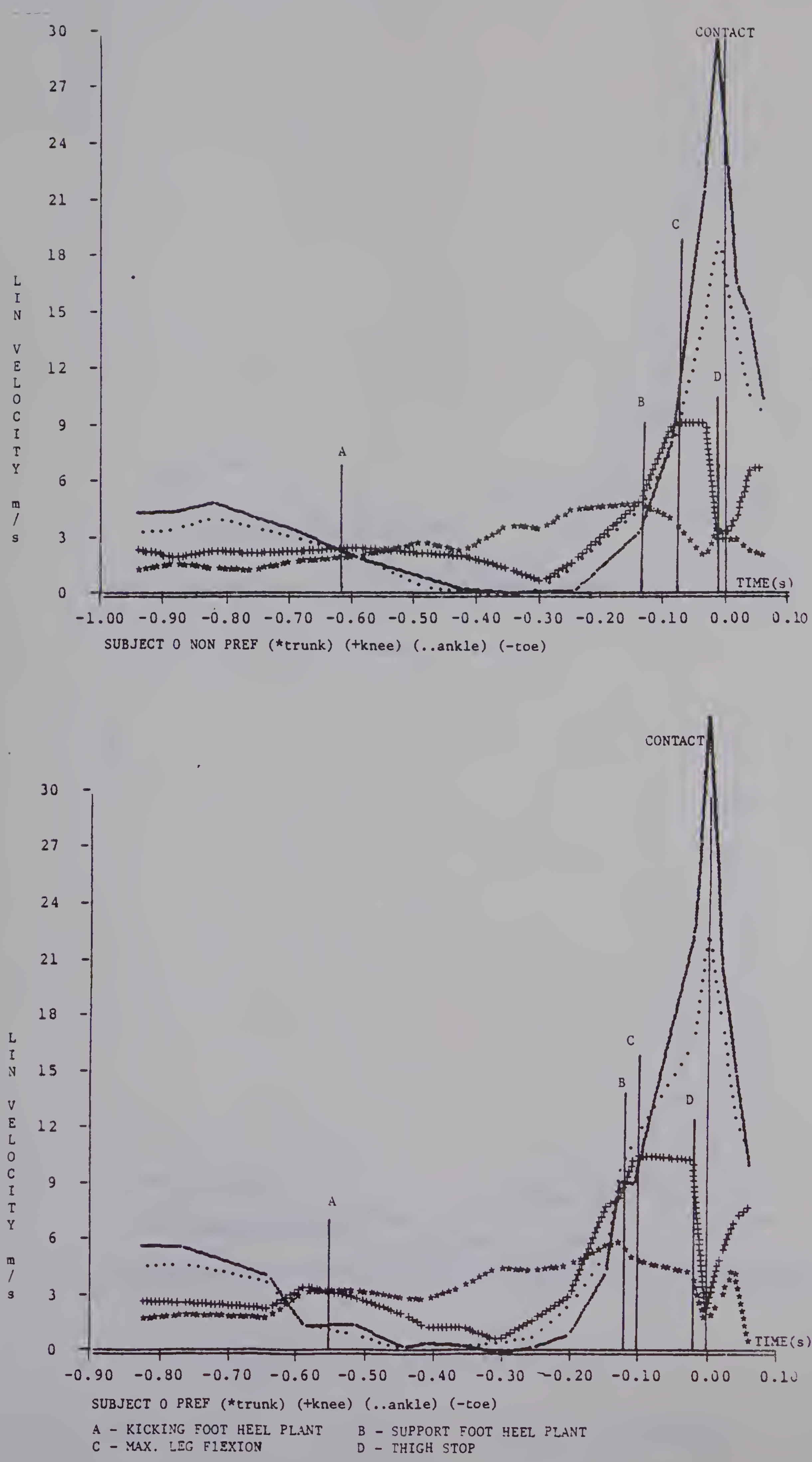


FIG. 32 LINEAR VELOCITY - SUBJECT 0 NON PREF & PREF FOOT

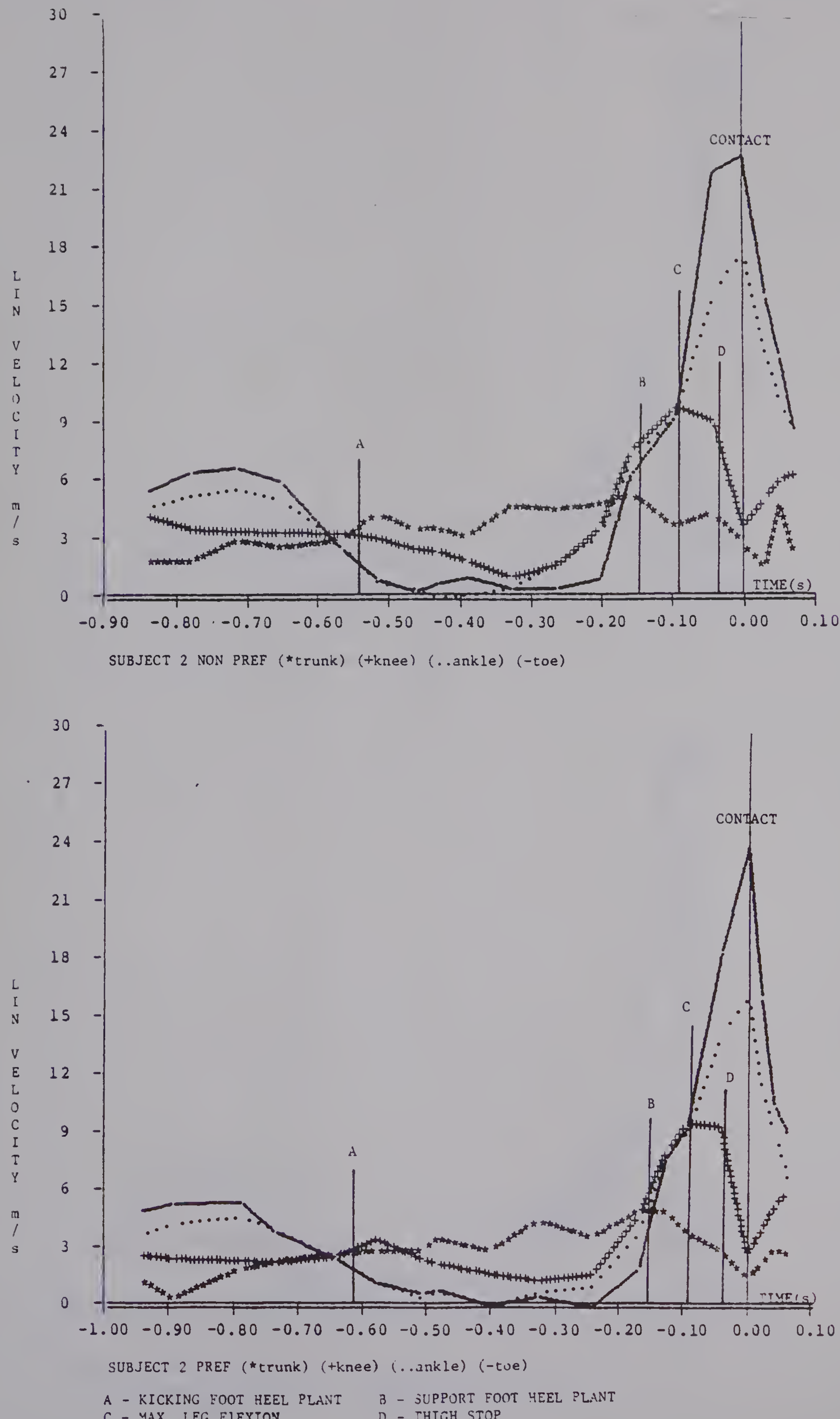


FIG. 33 LINEAR VELOCITY - SUBJECT 2 NON PREF & PREF FOOT

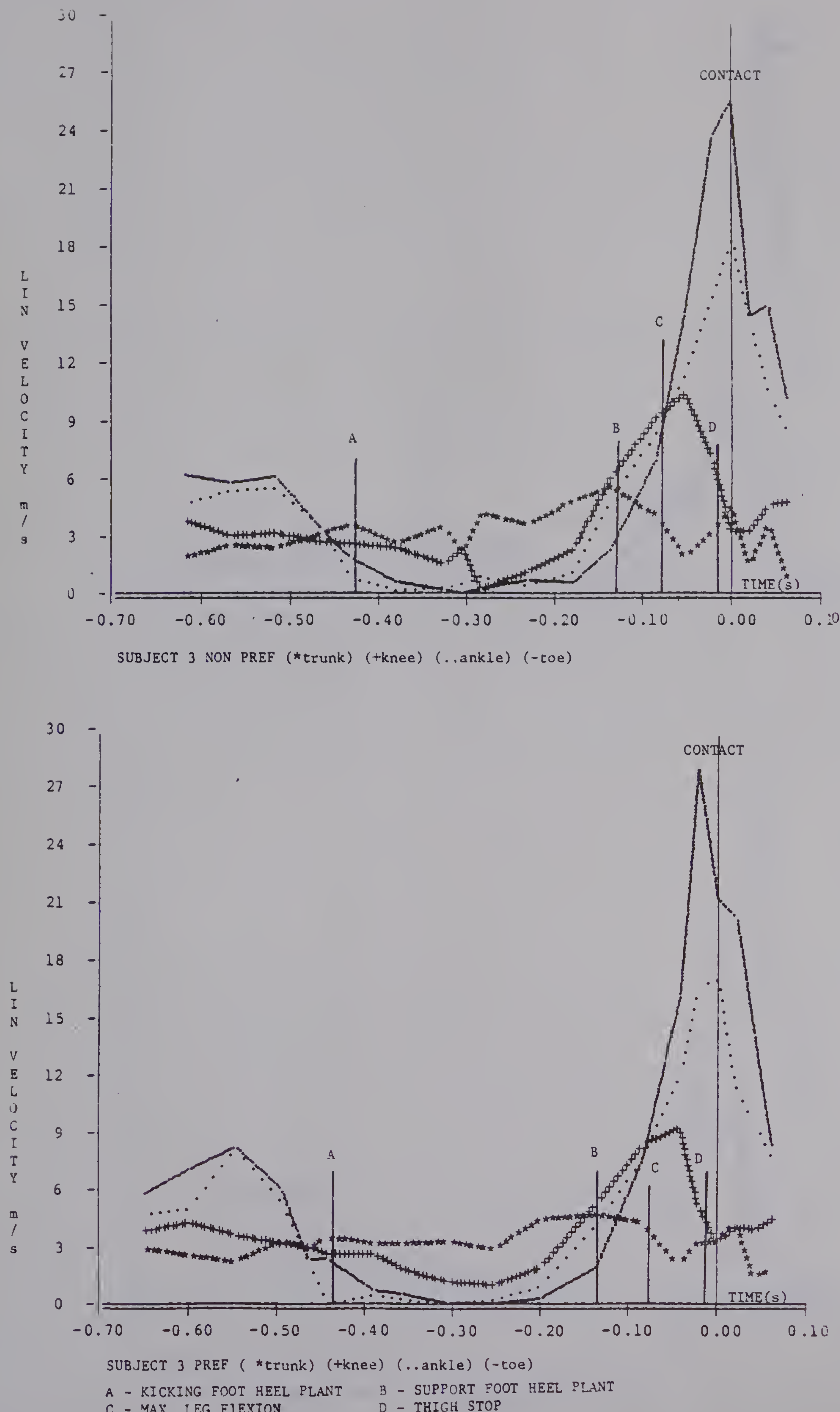


FIG. 34 LINEAR VELOCITY – SUBJECT 3 NON PREF & PREF FOOT

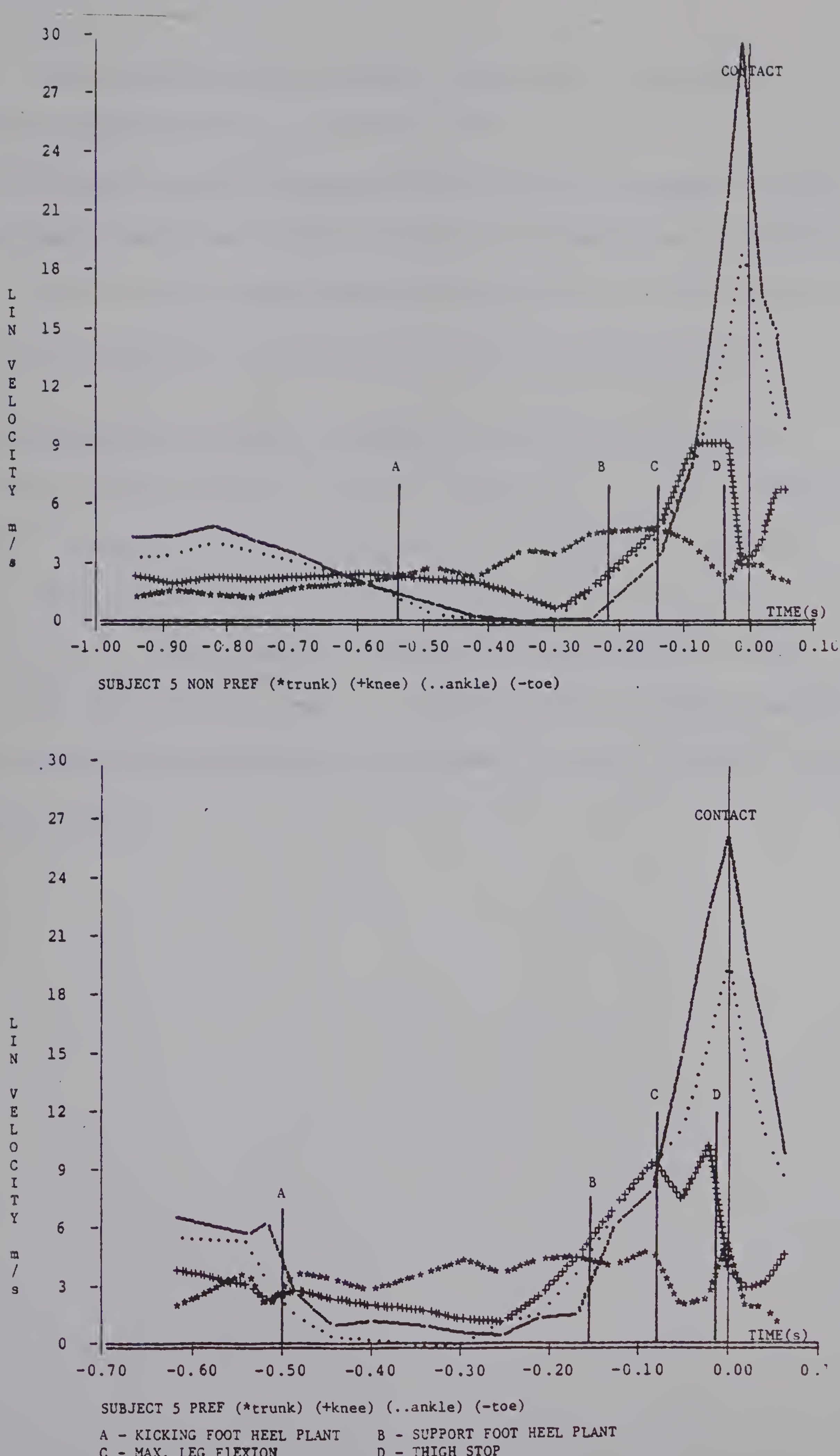


FIG. 35 LINEAR VELOCITY - SUBJECT 5 NON PREF & PREF FOOT

kick. The only exception is Subject 5 where the foot segment is slightly higher for the non preferred foot.

There are few differences in the fluctuating segmental linear velocities between the preferred and non preferred feet of Subjects 0, 2, 3 and 5. The maximum segment velocities of the preferred feet are the major differentiating factors between the two kicks.

Electromyography and Angular Velocity - Subjects 0, 2, 3 and 5

Raw data and graphical data for Subjects 0, 2, 3 and 5 segmental angular velocities and EMG recordings are presented in Appendix E. Electromyographical data and segmental angular velocity data for Subjects 0, 2, 3 and 5 indicate identical relationships to those presented for Subjects 1 and 4. Percentage EMG recordings increased and decreased in proportion to the segmental angular velocity changes of each segment.

DISCUSSION

The data reported was based on the kinematic and electromyographical analyses of six elite rugby players performing the rugby punt with both the preferred and non preferred kicking foot. Of the six subjects tested, two subjects were chosen for specific analysis and the selection was based on the mean distance kicked measured over three trials using both the preferred and non preferred foot. Subject 1 was the superior performer recording the highest average kicking distances for both preferred and non preferred feet. Subject 4 was the inferior performer recording significantly lower kicking distances, particularly on the non preferred foot.

In summary of the data reported for each of the parameters measured, the following observations were made. Angular accelerations of the trunk, thigh, leg and foot for Subjects 1 and 4 show particular differences which are more obvious in the non preferred foot of the inferior performer, Subject 4. The sequencing patterns of all segments were similar for both feet of Subject 1 and the preferred foot of Subject 4. The preferred side in all cases recorded greater ranges in segmental accelerations. The non preferred kicks of Subject 4 indicated variable fluctuations in segmental accelerations of all segments, particularly during the initial foot plant and swing phases. Although similar variations were shown in the preferred foot of Subject 4, the ranges were significantly less and maximum accelerations of the leg and foot, and markedly lower for the non preferred foot. The foot is reducing its angular acceleration in all kicks, immediately before ball contact; however levels are lower on the non

preferred sides. The angular ranges of movement for each of the joints show similar characteristics between both feet of Subject 1 and the preferred foot of Subject 4. Of all the parameters measured the least difference was shown between the angular ranges of all subjects. The non preferred side of Subject 4 shows slightly lower ranges of motion at all joints and a significant decrease at the ankle before contact. The trunk angle for both non preferred feet is decreasing while on the preferred side the trunk angle is increasing.

Velocity patterns for the centre of mass for both Subjects 1 and 4 are very similar with slightly higher levels for the preferred foot of Subject 1. Velocities peak for all subjects at support foot heel plant then decrease to contact. The non preferred feet of both subjects do not indicate any noticeable rise in velocity during or after contact, whereas the preferred feet show quite a marked increase. The linear velocities of the segmental end points show little difference between either foot for the superior performer, Subject 1. Maximum linear velocities for all segments are slightly lower for the non preferred foot, however the fluctuations in segmental velocity patterns are very similar. The inferior performer, on the preferred side, demonstrates similar segmental velocity characteristics to Subject 1. The non preferred foot of Subject 4 indicates lower maximum linear velocities of all segments with each segment increasing to the maximum over greater time periods. The maximum linear velocity of the foot is decreasing at contact for the non preferred and peaking on contact for the preferred foot.

The electromyographical data was based on the relationship between

EMG recordings of the Rectus Femoris, Biceps Femoris, Tibialis Anterior and the angular velocities of the thigh, leg and foot. High percentage EMG activity was shown for Biceps Femoris and Rectus Femoris when thigh and leg angular velocities were increasing during non preferred and preferred kicks for both Subjects 1 and 4. High concentration EMG levels were recorded just before and after support foot heel plant and were maintained at varying levels up to and after contact. Tibialis Anterior EMG activity did not indicate a direct relationship with foot velocities in all cases, particularly the preferred foot of Subject 1.

The kicking motion involves a series of sequentially rotating limb segments which begin angular motion before or at the point of support foot heel plant. Each segment including the trunk, the thigh, the leg and foot rotate at varying velocities through different ranges of joint motion to produce a final linear velocity of the foot segment at the point of contact with the ball. The effectiveness with which the kicker can rotate the limb segments to achieve a maximum final linear velocity of the foot is one of the necessary requirements of a successful rugby punt.

The relationship between angular velocity and linear velocity is an important concept in the understanding of human segmental limb motion, particularly motion of a ballistic nature. The linear velocity of the foot at the instant of impact is dependent on the length and the angular velocity of the segments involved.

$$V = r\omega$$

V = Linear Velocity

r = radius (length of segment)

ω = angular velocity

To achieve a greater linear velocity either the radius or the angular velocity must be increased. When the maximum angular velocity of a limb segment has been reached the linear velocity can be effectively increased by increasing the radius. In the case of the kick, if the maximum angular velocity of the thigh has been reached, the radius can be increased by extending the knee and therefore increasing the radius and the linear velocity of the foot. A similar process takes place between the leg and the foot. However, it is necessary to consider the position of the foot for impact rather than being overly concerned about maximizing the linear velocity of the segmental end point, the toe. When analyzing a kick it is important to consider the consistency with which the kicker maximizes the angular velocity of each segment before the radius is increased and the linear velocity of that segment is maximized.

The kicker may also develop higher segment angular velocities by shortening the radius. The extension of the thigh at the hip, and flexion of the leg at the knee are ways in which the kicker maximizes angular velocities before increasing the radius by thigh flexion and leg extension. The range of movement at the joint is therefore important so that maximum flexion or extension can be gained during angular segmental motion. Angular accelerations of the kickers' limb segments indicate the variation in the angular velocities. The rate of change in velocity or the speeding up and slowing down affect the final linear velocity of the impact segment. If the thigh is slowing down as the leg is extended to increase the radius, the final velocity of the foot will be less than if the thigh had reached its

maximum velocity.

$$\alpha = \frac{\omega o - \omega f}{t}$$

α = angular acceleration

ωf = final angular velocity

ωo = initial angular velocity

t = time

Although the present study is not directly concerned with a kinetic analysis of angular motion, the significance of angular momentum and its relationship to kinematic parameters is of some importance when considering an effective kicking motion

$$\text{Angular Momentum} = mr^2\omega$$

m = mass of body

r = radius

ω = angular velocity

Newton's first law states:

> "A body in rotation will continue to turn about the axis with an angular momentum constant in both magnitude and direction unless an external net torque is exerted on it."

The combined sum of all external torques acting on a body equals zero and the total angular momentum of the system is conserved and remains constant. These conditions are assumed for the rotation of human lower limb segments during the kick. The transfer of angular momentum is dependent on the mass of the segments (m), the length of the segment (r) and their angular velocity (ω). The mass of each limb segment is distributed about an axis of rotation, the joint. The moment of inertia of the limb ($I = mr^2$) is determined by the distribution of mass in each segment, the length of the segment and the range

of movement at the joint. Just as angular velocities were increased by shortening the radius during thigh extension and leg flexion, the moment of inertia can be reduced to enable the kicker to position the limb segments for the development of maximum angular velocities and maximum angular momentum. During the performance of a kick, momentum is transferred from a linear to an angular form then relayed through the segments to the kicking foot, where it is again transferred to the ball in the linear form. As the segmental masses are constant both the radius and the angular velocities vary so that angular momentum is transferred from one segment to another as the muscular torque forces rotate each segment. The total momentum of the system is conserved during the transferal provided there is no external force applied. In the case of the rugby punt, the external forces in consideration are the torque forces produced by contracting musculature.

During the approach the kicker will develop linear momentum which will be checked with the support foot heel plant. At this point there is a transfer or loss of momentum to the ground and the remainder is transferred into angular momentum through the trunk, the thigh, the leg and foot. The variations in the linear velocities of the centre of mass of the kicker indicate velocity decreases at support foot heel plant and momentum transferal. Linear momentum is transferred into the angular momentum of the trunk. The trunk rotates, reaching maximum angular velocities before decelerating due to external muscular torque. As the angular velocity of the trunk at support foot heel plant decreases, the moment of inertia increases. With the flexion of the thigh the momentum is transferred resulting in an increased angular

velocity of the thigh. As the thigh angular velocity decreases at the full forward knee position, the moment of inertia increases, and angular momentum is transferred into the leg in the form of an increased angular velocity. The angular momentum is conserved throughout the transferal process. As the leg decelerates the moment of inertia is reduced but the angular momentum is transferred onto the foot as a significant increase in angular velocity. The linear velocity of the foot at this point is maximized due to its reliance on the resulting high angular velocity ($V = r\omega$). Angular momentum has been maintained throughout the sequential increases and decreases in moment of inertia and the related decreases and increases in angular velocity. The greater mass of the larger segments, the trunk and thigh produce high moments of inertia which are transformed into increasingly high angular velocities as the angular momentum is progressively transferred along the lower limb to the foot and eventually the ball. The final transfer of angular momentum from the foot to the ball is based on a number of kinematic and kinetic variables, however, the present study is not concerned with the measurement of these variables. MACMILLAN (1975) discusses the concept of momentum transfer from the foot to the ball and suggests that the area requires more research, and is an important variable in the performance of any kick.

Significant differences in the angular accelerations of the limb segments for the non preferred foot of Subject 1 demonstrate decreases in angular acceleration levels both negative and positive. The preferred kicks for Subjects 4 and 1 indicate comparatively consistent increases with the leg and foot accelerating markedly as the thigh slows down. With decreasing angular velocities and relatively

consistent lever lengths the linear velocities for the inferior performer are therefore lower. Angular momentum is not being transferred efficiently from the linear form during the approach phase of the non preferred kick. The less obvious decreases in centre of mass velocities at support foot heel plant might suggest this. Angular ranges for the non preferred kick indicate slightly lower levels and therefore the possibility of reducing the angular distance over which angular velocities of the leg and thigh may be developed during full knee flexion and thigh extension. Evidence for these lower angular ranges is not great, possibly due to the relative high skill levels of the athletes.

Electromyographic activity in the lower limb musculature indicates a direct relationship to changes in the angular velocity of the thigh, leg and foot. No attempt was made to relate the level of contraction to the velocity changes, however, the sequencing of EMG and segment motion was recorded. Musculature is capable of contraction when lengthening and shortening and it is through the torque forces exerted by the musculature that angular limb segment motion is controlled. It is through these torque forces that limb segment angular velocities are increased and reduced therefore controlling moment of inertia and subsequent angular momentum transferal. EMG levels are recorded when the segment is rotating either clockwise or anticlockwise, that is, when the segment has a negative or positive angular acceleration. The torque forces controlling this motion are indicated through EMG activity of the Rectus Femoris, Biceps Femoris and Tibialis Anterior. The Rectus Femoris and Biceps Femoris cross the hip and knee and therefore contract both eccentrically (lengthen) and concentrically

(shorten) to control thigh and leg rotation during the kicking motion.

The relationship between EMG recordings and changing angular velocities of the limb segments for all kicks both preferred and non preferred followed a fairly consistent pattern. EMG activity from the Rectus Femoris was recorded before and after kicking foot heel plant when the muscle was stabilizing the hip and trunk during force transferal. Additional activity resulted at the beginning of the swing phase, then dropped off to minimal levels. The swing phase period was relatively low in percentage EMG indicating minimal contraction either eccentric or concentric. Noticeably high levels were recorded in the Rectus Femoris during leg flexion and thigh extension when the muscle was lengthening during eccentric contraction. Increasing EMG percentages reached maximum during leg extension and thigh flexion immediately before contact. The muscle is contracting concentrically during this particular phase and due to the two joint nature of the muscle it is impossible to distinguish at which joint the majority of the torque force is being applied at any one moment. Maximum angular velocities of the thigh and leg, particularly the leg, relate closely to maximum EMG levels in the Rectus Femoris. The Biceps Femoris muscle recorded activity levels at kicking foot heel plant where, as with the quadriceps group, the hip and knee are being stabilized during weight transferal. Intermittent and fluctuating EMG levels below 50% were recorded during the swing phase when the hamstring group would be lengthening and contracting eccentrically. Heavy activity was recorded during leg flexion and thigh extension when the muscle was contracting concentrically. As the leg is extended and the thigh flexed, angular velocities of the thigh and leg increase with concentric quadriceps contraction.

The Biceps Femoris activity decreases and does not increase again until contact of approximately one second after, when thigh and leg ballistic motion must be controlled through eccentric torque forces from the hamstring group.

Tibialis Anterior EMG activity was not consistent with the changes in angular velocities of the foot for all subjects, both preferred and non preferred feet. The most pronounced activity in the Tibialis Anterior was recorded particularly at the non preferred kick when the foot increased its angular velocity at the ankle before and during ball contact. Most of the preferred kicks maintain an extended ankle and lower EMG levels are recorded. Tibialis activity is also evident during the push off phase of kicking foot heel plant for all kicks, both preferred and non preferred.

The angular motion of the foot and the angle at which the foot contacts the ball are variables which are controlled to some degree by Tibialis Anterior. Flexion of the foot at the ankle is initiated by the Tibialis and would possibly play an important role in controlling the position of the foot at the point of impact.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

The purpose of the present study was to investigate and measure the kinematic and electromyographical parameters of the rugby punt when performed for maximum distance using the preferred and non preferred kicking foot. Two dimensional high speed cinematography synchronized with electromyographic recordings of the lower extremity musculature was used for the testing procedure. The film was used for the testing procedure. The film was analyzed to measure the kinematic and muscular contraction variations in limb segment motion. Kinematic data included angular segmental accelerations, linear segmental accelerations, ranges of joint motion and the velocities of the centre of mass for six elite subjects performing the rugby punt with both the preferred and non preferred foot. Electromyographic recordings were recorded simultaneously for the Rectus Femoris, Biceps Femoris and Tibialis Anterior of the kicking leg. Two subjects were chosen to demonstrate the differences between the superior kicker using both preferred and non preferred feet and the inferior kicker using the non preferred foot. The selection of the two subjects for comparison was based on kicking distances. Results indicated inferior performances for the non preferred foot of all subjects and considerable variation in kinematic data was demonstrated for all subjects, in particular the inferior performer. The sequencing of segmental angular velocity variations was suggested as being a factor in the lack of performance with the non preferred foot. Electromyographical recordings indicated a close

relationship between segmental angular velocities and EMG percentages of maximum contraction for both the Rectus Femoris and Biceps Femoris. There were no obvious differences in the EMG patterns for the preferred and non preferred feet of all subjects. EMG levels for Tibialis Anterior were not consistent for all subjects but were related to the degree of motion at the ankle during and before contact with the ball.

It was concluded that the inferior performances demonstrated by the inferior kickers using the non preferred foot was a result of the failure of the kicker to effectively maintain the necessary kinematic segmental sequencing processes. Failure to effectively control segmental motion affected momentum transfer through the limb segments and the final momentum transfer to the ball at impact. Electromyographical activity indicated concentric muscular contraction which initiated segmental motion during the earlier stages of the movement. Eccentric contraction of alternate musculature controlled the segmental motion during the final stages of limb motion. EMG levels dropped off during the swing phase of the approach indicating that the concentric contraction initiated the motion but was not necessary to maintain it. EMG levels were highest during the maximum segmental angular velocity periods, however, it was impossible to distinguish the degree of muscular contraction at the specific joints which were controlled by the two joint muscles, Rectus Femoris and Biceps Femoris.

The following recommendations are made:

1) It must be acknowledged that there is a definite need for the development of equally effective skills using both preferred and non preferred sides of the body. The versatility of an athlete in being able to alternate from left to right and right to left when performing

complex skills is a result of the learning, teaching and coaching processes. With this in mind it is important for coaches to emphasize the teaching and development of these skills rather than allow the athlete to develop naturally toward a preferred side of the body. In recognition of this fact, detailed biomechanical analyses of skills which may be performed using both sides of the body, should be carried out and the necessary adaptions made by the coach during the learning process.

2) A repeat of the present study dealing with athletes at various stages of the skill learning process, ranging from the beginner through intermediate to advanced.

3) The effects of practice and direct coaching techniques on the performance of athletes learning to use the non preferred limbs.

4) A more in-depth study and measurement of the kick as it relates to momentum transfer from foot to ball on contact. High speed three-dimensional photography concentrating on ankle range, foot shape, contact surface and ball ballistics is necessary to completely understand the nature of the kick. The suggestion is that a developing kicker may have all the necessary limb segment motions but the ball is not making contact at the correct time or at the correct position on the foot.

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APPENDICES

APPENDIX A

ANGULAR ACCELERATION DATA

ANGULAR KINEMATICS : TRUNK SUBJECT 0 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	0.00	0.04	
2				-0.42
	0.063	0.00	0.01	
3				-8.32
	0.126	-0.06	-0.48	
4				4.35
	0.053	0.02	0.43	
5				7.23
	0.074	0.01	0.16	
6				-18.98
	0.074	-0.06	-0.77	
7				-10.89
	0.032	-0.02	-0.64	
8				20.22
	0.053	0.02	0.29	
9				46.42
	0.053	0.07	1.31	
10				17.22
	0.053	0.06	1.20	
11				8.78
	0.053	0.09	1.77	
12				39.26
	0.053	0.17	3.26	
13				30.96
	0.021	0.07	3.40	
14				-27.91
	0.021	0.05	2.23	
15				-88.09
	0.084	0.13	1.55	
16				-130.14
	0.021	-0.10	-4.60	
17				-29.97
	0.021	-0.00	-0.02	
18				238.19
	0.021	0.01	0.40	
19				-234.93
	0.021	-0.10	-4.53	
20				

ANGULAR KINEMATICS : R. THIGH SUBJECT 0 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	0.11	1.68	
2				-1.99
	0.063	0.10	1.56	
3				3.95
	0.126	0.24	1.93	
4				-27.03
	0.053	-0.05	-1.00	
5				-35.73
	0.074	-0.09	-1.26	
6				-17.73
	0.074	-0.16	-2.12	
7				-23.10
	0.032	-0.09	-2.96	
8				-27.88
	0.053	-0.19	-3.58	
9				-36.94
	0.053	-0.24	-4.51	
10				-8.84
	0.053	-0.21	-4.04	
11				18.24
	0.053	-0.19	-3.55	
12				131.46
	0.053	0.15	2.86	
13				165.47
	0.021	0.11	5.14	
14				155.23
	0.021	0.18	8.56	
15				295.82
	0.084	0.95	11.35	
16				-198.45
	0.021	-0.04	-1.86	
17				-102.42
	0.021	0.13	5.97	
18				575.65
	0.021	0.21	10.23	
19				-41.08
	0.021	0.20	9.37	
20				

ANGULAR KINEMATICS : R.LOWER LEG SUBJECT 0 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	0.27	4.26	
2				-3.61
	0.063	0.25	4.03	
3				-27.80
	0.126	0.32	2.50	
4				-69.14
	0.053	-0.13	-2.51	
5				-65.35
	0.074	-0.24	-3.33	
6				-5.21
	0.074	-0.21	-2.83	
7				23.30
	0.032	-0.05	-1.62	
8				22.00
	0.053	-0.09	-1.68	
9				4.21
	0.053	-0.08	-1.44	
10				-6.63
	0.053	-0.11	-2.03	
11				-33.66
	0.053	-0.17	-3.21	
12				-169.42
	0.053	-0.57	-10.92	
13				-102.63
	0.021	-0.18	-8.59	
14				232.90
	0.021	-0.05	-2.36	
15				-391.78
	0.084	-1.41	-16.82	
16				672.03
	0.021	0.69	32.92	
17				692.18
	0.021	0.41	19.52	
18				-1119.65
	0.021	0.20	9.41	
19				-193.95
	0.021	0.11	5.33	
20				

ANGULAR KINEMATICS : R. FOOT SUBJECT 0 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	0.36	5.72	
2				0.68
	0.063	0.36	5.76	
3				-34.74
	0.126	0.44	3.53	
4				-79.29
	0.053	-0.09	-1.73	
5				-81.86
	0.074	-0.28	-3.78	
6				8.05
	0.074	-0.09	-1.23	
7				30.38
	0.032	-0.05	-1.55	
8				-0.32
	0.053	-0.07	-1.24	
9				26.17
	0.053	-0.02	-0.45	
10				-63.38
	0.053	-0.24	-4.57	
11				-182.22
	0.053	-0.53	-10.01	
12				-247.65
	0.053	-0.92	-17.57	
13				-22.06
	0.021	-0.23	-11.17	
14				225.32
	0.021	-0.20	-9.29	
15				-230.78
	0.084	-1.35	-16.02	
16				1158.62
	0.021	1.08	51.53	
17				561.83
	0.021	0.28	13.48	
18				-1778.99
	0.021	0.30	14.18	
19				-738.25
	0.021	-0.03	-1.33	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 0 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	0.04	0.56	
2				-3.60
	0.063	0.02	0.34	
3				4.02
	0.063	0.05	0.81	
4				4.85
	0.063	0.04	0.64	
5				-10.29
	0.063	0.01	0.17	
6				-3.88
	0.105	0.04	0.40	
7				-2.36
	0.105	-0.00	-0.03	
8				7.46
	0.063	0.07	1.18	
9				-8.24
	0.074	-0.05	-0.72	
10				-25.49
	0.053	-0.03	-0.56	
11				-15.97
	0.053	-0.09	-1.73	
12				-39.18
	0.105	-0.27	-2.62	
13				-11.88
	0.053	-0.14	-2.67	
14				59.52
	0.053	0.11	2.07	
15				2.96
	0.021	-0.05	-2.51	
16				28.14
	0.011	0.03	3.11	
17				151.76
	0.021	-0.00	-0.12	
18				-3.02
	0.021	0.06	3.06	
19				-50.78
	0.021	0.04	1.99	
20				

ANGULAR KINEMATICS : L. THIGH SUBJECT 0 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	-0.10	-1.64	
2				-0.67
	0.063	-0.11	-1.68	
3				6.58
	0.063	-0.08	-1.22	
4				-8.75
	0.063	-0.14	-2.23	
5				-4.82
	0.063	-0.10	-1.53	
6				7.76
	0.105	-0.18	-1.74	
7				41.68
	0.105	0.21	1.97	
8				49.66
	0.063	0.22	3.47	
9				9.09
	0.074	0.20	2.74	
10				25.18
	0.053	0.27	5.19	
11				50.90
	0.053	0.31	5.94	
12				-99.74
	0.105	-0.01	-0.05	
13				-220.50
	0.053	-0.60	-11.42	
14				-159.39
	0.053	-0.66	-12.60	
15				364.37
	0.021	0.16	7.71	
16				48.33
	0.011	-0.11	-10.82	
17				-881.23
	0.021	-0.13	-6.17	
18				4.86
	0.021	-0.23	-10.75	
19				206.46
	0.021	-0.13	-6.41	
20				

ANGULAR KINEMATICS : L.LOWER LEG SUBJECT 0 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	-0.26	-4.09	
2				3.14
	0.063	-0.25	-3.89	
3				-12.76
	0.063	-0.31	-4.90	
4				10.10
	0.063	-0.21	-3.26	
5				46.88
	0.063	-0.12	-1.94	
6				59.28
	0.105	0.05	0.48	
7				60.47
	0.105	0.33	3.14	
8				25.96
	0.063	0.20	3.20	
9				-6.94
	0.074	0.19	2.55	
10				-41.45
	0.053	0.02	0.37	
11				-21.93
	0.053	0.06	1.17	
12				152.30
	0.105	0.88	8.37	
13				-37.47
	0.053	-0.09	-1.78	
14				-395.22
	0.053	-1.19	-22.75	
15				-649.48
	0.021	-0.75	-35.88	
16				-202.59
	0.011	-0.32	-30.20	
17				1044.40
	0.021	-0.41	-19.43	
18				1424.98
	0.021	-0.16	-7.76	
19				92.49
	0.021	-0.12	-5.81	
20				

ANGULAR KINEMATICS : L. FOOT SUBJECT 0 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	-0.33	-5.18	
2				17.90
	0.063	-0.26	-4.05	
3				-23.82
	0.063	-0.42	-6.68	
4				-24.21
	0.063	-0.35	-5.57	
5				56.94
	0.063	-0.19	-3.09	
6				86.09
	0.105	-0.02	-0.15	
7				84.17
	0.105	0.42	3.98	
8				-7.59
	0.063	-0.06	-0.95	
9				-28.50
	0.074	0.12	1.59	
10				59.07
	0.053	0.16	3.08	
11				70.01
	0.053	0.31	6.00	
12				222.28
	0.105	1.55	14.75	
13				-67.00
	0.053	0.04	0.72	
14				-545.45
	0.053	-1.48	-28.20	
15				-617.30
	0.021	-0.67	-31.69	
16				233.60
	0.011	-0.21	-19.62	
17				1120.11
	0.021	-0.29	-14.05	
18				120.99
	0.021	-0.37	-17.71	
19				435.56
	0.021	-0.18	-8.56	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT1 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.032	-0.03	-0.81	
2				2.20
	0.042	-0.03	-0.73	
3				7.89
	0.032	-0.02	-0.52	
4				27.25
	0.053	0.01	0.27	
5				-15.92
	0.053	-0.06	-1.19	
6				7.24
	0.084	0.05	0.65	
7				-2.15
	0.074	-0.10	-1.34	
8				-26.70
	0.053	-0.08	-1.45	
9				9.14
	0.053	-0.04	-0.76	
10				8.43
	0.053	-0.05	-1.01	
11				-52.24
	0.063	-0.22	-3.50	
12				-13.41
	0.074	-0.13	-1.78	
13				-10.35
	0.021	-0.09	-4.21	
14				4.91
	0.021	-0.03	-1.55	
15				162.17
	0.053	-0.04	-0.80	
16				-67.46
	0.011	-0.04	-4.03	
17				48.28
	0.021	0.02	0.72	
18				155.02
	0.021	-0.03	-1.57	
19				-25.62
	0.021	-0.04	-2.11	
20				

ANGULAR KINEMATICS : L. THIGH SUBJECT1 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.032	0.04	1.13	
2				-52.24
	0.042	-0.03	-0.79	
3				-43.91
	0.032	-0.02	-0.48	
4				54.26
	0.053	0.06	1.20	
5				37.93
	0.053	0.06	1.11	
6				41.51
	0.084	0.28	3.38	
7				43.17
	0.074	0.30	4.05	
8				32.41
	0.053	0.31	5.93	
9				-5.63
	0.053	0.19	3.70	
10				-81.25
	0.053	0.09	1.67	
11				-112.98
	0.063	-0.14	-2.23	
12				-220.35
	0.074	-0.81	-11.06	
13				-145.74
	0.021	-0.26	-12.18	
14				-42.83
	0.021	-0.27	-13.08	
15				286.30
	0.053	-0.32	-6.17	
16				328.30
	0.011	-0.01	-1.01	
17				195.12
	0.021	-0.00	-0.02	
18				-156.98
	0.021	-0.07	-3.49	
19				-150.78
	0.021	-0.14	-6.65	
20				

ANGULAR KINEMATICS : L.LOWER LEG SUBJECT1 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.032	-0.12	-3.67	
2				122.08
	0.042	0.03	0.81	
3				254.76
	0.032	0.18	5.69	
4				82.38
	0.053	0.20	3.84	
5				-50.42
	0.053	0.19	3.57	
6				-26.92
	0.084	0.20	2.43	
7				-41.76
	0.074	0.05	0.72	
8				-27.98
	0.053	0.01	0.22	
9				-0.29
	0.053	0.04	0.70	
10				95.60
	0.053	0.28	5.24	
11				190.12
	0.063	0.67	10.68	
12				-75.88
	0.074	0.06	0.86	
13				-333.91
	0.021	-0.26	-12.45	
14				-512.05
	0.021	-0.49	-23.33	
15				-679.71
	0.053	-1.40	-26.72	
16				-137.97
	0.011	-0.30	-28.40	
17				257.93
	0.021	-0.39	-18.60	
18				752.89
	0.021	-0.35	-16.55	
19				352.48
	0.021	-0.19	-9.14	
20				

ANGULAR KINEMATICS : L. FOOT SUBJECT1 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.032	-0.02	-0.55	
2				123.45
	0.042	0.17	3.98	
3				97.17
	0.032	0.10	3.02	
4				-9.50
	0.053	0.19	3.63	
5				-53.55
	0.053	0.04	0.77	
6				-45.05
	0.084	0.09	1.11	
7				39.18
	0.074	0.25	3.44	
8				47.57
	0.053	0.26	4.86	
9				76.09
	0.053	0.43	8.24	
10				5.82
	0.053	0.27	5.16	
11				81.62
	0.063	0.79	12.52	
12				-31.80
	0.074	0.24	3.33	
13				-386.89
	0.021	-0.29	-13.88	
14				-578.17
	0.021	-0.50	-23.99	
15				-616.35
	0.053	-1.41	-26.83	
16				-562.05
	0.011	-0.47	-44.65	
17				435.79
	0.021	-0.28	-13.10	
18				980.35
	0.021	-0.61	-29.21	
19				836.06
	0.021	-0.22	-10.60	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 1 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.105	-0.12	-1.12	
2				3.92
	0.105	-0.07	-0.71	
3				9.01
	0.105	-0.02	-0.17	
4				19.43
	0.021	0.03	1.33	
5				46.70
	0.021	0.06	2.77	
6				-86.47
	0.126	-0.06	-0.48	
7				-41.12
	0.063	-0.02	-0.25	
8				11.31
	0.126	0.07	0.59	
9				14.17
	0.053	0.06	1.09	
10				17.64
	0.053	0.11	2.16	
11				19.54
	0.053	0.11	2.11	
12				34.85
	0.053	0.21	3.99	
13				36.22
	0.042	0.17	4.01	
14				-103.28
	0.032	-0.03	-0.89	
15				-3.78
	0.042	0.16	3.87	
16				27.67
	0.032	0.00	0.13	
17				-121.59
	0.021	-0.01	-0.59	
18				-35.90
	0.021	-0.02	-0.82	
19				-43.11
	0.021	-0.04	-1.72	
20				

ANGULAR KINEMATICS : R. THIGH SUBJECT 1 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.105	0.35	3.33	
2				-24.59
	0.105	0.08	0.75	
3				-27.38
	0.105	0.05	0.45	
4				-4.18
	0.021	0.01	0.31	
5				-6.47
	0.021	0.00	0.05	
6				-85.25
	0.126	-0.19	-1.48	
7				-51.82
	0.063	-0.24	-3.76	
8				-15.04
	0.126	-0.37	-2.90	
9				-7.36
	0.053	-0.23	-4.46	
10				-31.91
	0.053	-0.30	-5.75	
11				62.36
	0.053	-0.06	-1.18	
12				176.50
	0.053	0.18	3.51	
13				192.55
	0.042	0.37	8.93	
14				283.61
	0.032	0.53	16.92	
15				84.73
	0.042	0.51	12.04	
16				-405.41
	0.032	0.06	2.02	
17				-312.63
	0.021	0.01	0.55	
18				143.13
	0.021	0.12	5.77	
19				188.90
	0.021	0.20	9.74	
20				

ANGULAR KINEMATICS : R.LOWER LEG SUBJECT 1 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.105	0.58	5.52	
2				1.61
	0.105	0.60	5.69	
3				-40.25
	0.105	0.14	1.29	
4				-72.76
	0.021	-0.04	-1.95	
5				-82.53
	0.021	-0.08	-3.91	
6				-88.05
	0.126	-0.48	-3.80	
7				15.02
	0.063	-0.18	-2.80	
8				19.01
	0.126	-0.25	-2.00	
9				11.64
	0.053	-0.09	-1.70	
10				15.11
	0.053	-0.03	-0.66	
11				-80.27
	0.053	-0.31	-5.92	
12				-145.66
	0.053	-0.44	-8.30	
13				84.30
	0.042	-0.06	-1.49	
14				387.60
	0.032	0.32	10.01	
15				691.42
	0.042	1.00	23.92	
16				565.29
	0.032	0.97	30.79	
17				-12.56
	0.021	0.49	23.46	
18				-552.22
	0.021	0.34	16.29	
19				-362.85
	0.021	0.18	8.67	
20				

ANGULAR KINEMATICS : R. FOOT SUBJECT 1 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.105	0.55	5.29	
2				6.39
	0.105	0.63	5.96	
3				-32.68
	0.105	0.19	1.85	
4				-111.30
	0.021	-0.12	-5.73	
5				-89.00
	0.021	-0.08	-3.75	
6				129.43
	0.126	-0.38	-3.01	
7				28.77
	0.063	-0.10	-1.64	
8				11.34
	0.126	-0.24	-1.94	
9				-58.85
	0.053	-0.38	-7.20	
10				-72.17
	0.053	-0.44	-8.38	
11				-16.23
	0.053	-0.42	-8.05	
12				-12.81
	0.053	-0.48	-9.05	
13				29.29
	0.042	-0.27	-6.51	
14				421.28
	0.032	0.34	10.85	
15				856.02
	0.042	1.05	24.95	
16				508.46
	0.032	0.93	29.54	
17				106.67
	0.021	0.61	28.87	
18				-305.82
	0.021	0.45	21.51	
19				-764.79
	0.021	0.11	5.45	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 2 NON PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	-0.05	-0.87	
2				-2.40
	0.063	-0.06	-1.02	
3				25.11
	0.063	0.04	0.71	
4				10.07
	0.063	-0.02	-0.39	
5				-5.18
	0.084	0.03	0.39	
6				17.57
	0.053	0.05	0.91	
7				-0.07
	0.053	0.02	0.38	
8				-15.37
	0.032	0.00	0.10	
9				-5.05
	0.042	0.01	0.17	
10				41.81
	0.063	0.10	1.64	
11				13.92
	0.063	0.06	0.90	
12				7.27
	0.063	0.13	2.09	
13				26.47
	0.042	0.11	2.57	
14				-13.39
	0.063	0.09	1.39	
15				-3.24
	0.053	0.13	2.40	
16				-15.51
	0.042	0.02	0.49	
17				-67.64
	0.032	-0.03	-0.80	
18				-12.43
	0.021	0.00	0.04	
19				-61.00
	0.021	-0.03	-1.24	
20				

ANGULAR KINEMATICS : R. THIGH SUBJECT 2 NON PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELLERATION rad/sec/sec
1				
	0.063	0.20	3.14	
2				-8.71
	0.063	0.16	2.59	
3				-10.14
	0.063	0.16	2.50	
4				-24.00
	0.063	0.07	1.08	
5				-53.69
	0.084	-0.07	-0.88	
6				-42.48
	0.053	-0.11	-2.04	
7				-17.79
	0.053	-0.11	-2.10	
8				10.52
	0.032	-0.05	-1.49	
9				-9.18
	0.042	-0.10	-2.48	
10				-63.93
	0.063	-0.24	-3.84	
11				-54.17
	0.063	-0.34	-5.33	
12				15.73
	0.063	-0.18	-2.85	
13				158.58
	0.042	0.20	4.66	
14				246.21
	0.063	0.63	10.08	
15				61.08
	0.053	0.41	7.87	
16				-134.45
	0.042	0.10	2.31	
17				28.15
	0.032	0.29	9.20	
18				110.82
	0.021	0.13	6.38	
19				198.43
	0.021	0.22	10.55	
20				

ANGULAR KINEMATICS : R.LOWER LEG SUBJECT 2 NON PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	0.19	3.04	
2				24.71
	0.063	0.29	4.60	
3				27.95
	0.063	0.30	4.80	
4				-15.59
	0.063	0.23	3.62	
5				-83.31
	0.084	-0.04	-0.44	
6				-103.84
	0.053	-0.21	-4.02	
7				-44.97
	0.053	-0.18	-3.51	
8				0.82
	0.032	-0.13	-3.97	
9				25.76
	0.042	-0.10	-2.43	
10				60.06
	0.063	-0.11	-1.77	
11				39.31
	0.063	-0.02	-0.37	
12				-13.53
	0.063	-0.16	-2.62	
13				-138.62
	0.042	-0.38	-9.10	
14				64.34
	0.063	0.05	0.76	
15				576.24
	0.053	1.11	21.15	
16				468.16
	0.042	1.17	27.80	
17				-158.72
	0.032	0.43	13.65	
18				-524.96
	0.021	0.18	8.50	
19				-195.70
	0.021	0.09	4.39	
20				

ANGULAR KINEMATICS : L. FOOT SUBJECT 2 NON PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.063	0.30	4.68	
2				5.24
	0.063	0.32	5.01	
3				29.96
	0.063	0.41	6.57	
4				28.20
	0.063	0.43	6.79	
5				-109.70
	0.084	-0.03	-0.34	
6				-156.43
	0.053	-0.25	-4.71	
7				-0.76
	0.053	-0.02	-0.39	
8				152.28
	0.032	0.10	3.29	
9				-116.05
	0.042	-0.22	-5.27	
10				-193.51
	0.063	-0.24	-3.82	
11				-9.14
	0.063	-0.36	-5.75	
12				-123.49
	0.063	-0.73	-11.60	
13				-109.97
	0.042	-0.53	-12.67	
14				185.91
	0.063	-0.12	-1.84	
15				-308.18
	0.053	-1.51	-28.85	
16				339.16
	0.042	0.75	17.74	
17				962.79
	0.032	0.52	16.64	
18				-238.88
	0.021	0.19	8.96	
19				-158.63
	0.021	0.12	5.63	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 2 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	0.06	1.06	
2				13.79
	0.053	0.09	1.78	
3				-13.50
	0.105	0.04	0.35	
4				-23.23
	0.053	-0.00	-0.05	
5				-10.48
	0.095	-0.04	-0.47	
6				-1.50
	0.063	-0.01	-0.16	
7				12.63
	0.074	0.04	0.52	
8				-19.19
	0.021	-0.03	-1.46	
9				-16.79
	0.084	-0.02	-0.27	
10				-6.35
	0.074	-0.13	-1.80	
11				-3.66
	0.084	-0.05	-0.56	
12				-15.51
	0.074	-0.22	-3.02	
13				-31.90
	0.042	-0.13	-3.07	
14				12.79
	0.032	-0.07	-2.28	
15				112.17
	0.053	0.06	1.05	
16				86.88
	0.042	0.06	1.37	
17				6.95
	0.021	0.03	1.38	
18				0.36
	0.021	0.03	1.38	
19				39.97
	0.021	0.05	2.22	
20				

ANGULAR KINEMATICS : L. THIGH SUBJECT 2 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	-0.08	-1.46	
2				-4.92
	0.053	-0.09	-1.72	
3				19.11
	0.105	-0.05	-0.46	
4				-0.47
	0.053	-0.09	-1.76	
5				-9.01
	0.095	-0.11	-1.17	
6				37.10
	0.063	0.06	0.97	
7				36.62
	0.074	0.13	1.71	
8				29.78
	0.021	0.06	3.00	
9				21.39
	0.084	0.23	2.72	
10				-0.19
	0.074	0.22	2.99	
11				35.33
	0.084	0.46	5.51	
12				-36.09
	0.074	0.01	0.15	
13				-171.71
	0.042	-0.34	-8.02	
14				-213.44
	0.032	-0.38	-12.18	
15				-104.19
	0.053	-0.62	-11.84	
16				239.70
	0.042	-0.09	-2.11	
17				49.57
	0.021	-0.20	-9.50	
18				-207.97
	0.021	-0.18	-8.66	
19				74.63
	0.021	-0.15	-7.09	
20				

ANGULAR KINEMATICS : L.LOWER LEG SUBJECT 2 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	-0.25	-4.71	
2				-5.45
	0.053	-0.26	-5.00	
3				-12.35
	0.105	-0.56	-5.36	
4				19.90
	0.053	-0.18	-3.43	
5				66.29
	0.095	-0.01	-0.14	
6				104.52
	0.063	0.27	4.25	
7				50.85
	0.074	0.28	3.87	
8				-6.96
	0.021	0.08	3.78	
9				-13.09
	0.084	0.27	3.25	
10				-25.56
	0.074	0.18	2.44	
11				-28.72
	0.084	0.08	0.99	
12				24.99
	0.074	0.32	4.41	
13				87.61
	0.042	0.33	7.89	
14				-159.87
	0.032	-0.15	-4.83	
15				-809.56
	0.053	-1.15	-21.87	
16				-606.19
	0.042	-1.27	-30.29	
17				141.38
	0.021	-0.32	-15.19	
18				712.71
	0.021	-0.16	-7.84	
19				299.57
	0.021	-0.03	-1.55	
20				

ANGULAR KINEMATICS : L. FOOT SUBJECT 2 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	-0.24	-4.65	
2				-10.98
	0.053	-0.27	-5.23	
3				-29.14
	0.105	-0.65	-6.18	
4				-40.03
	0.053	-0.44	-8.38	
5				93.22
	0.095	0.11	1.16	
6				112.60
	0.063	-0.01	-0.11	
7				47.61
	0.074	0.36	4.91	
8				59.41
	0.021	0.08	3.95	
9				-82.86
	0.084	0.08	0.99	
10				51.07
	0.074	0.49	6.63	
11				48.49
	0.084	0.40	4.81	
12				49.57
	0.074	0.77	10.53	
13				59.13
	0.042	0.40	9.47	
14				-193.12
	0.032	-0.02	-0.62	
15				-834.17
	0.053	-1.11	-21.19	
16				-693.07
	0.042	-1.25	-29.73	
17				73.85
	0.021	-0.37	-17.46	
18				610.31
	0.021	-0.22	-10.50	
19				70.29
	0.021	-0.19	-9.03	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 3 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.105	0.12	1.15	
2				-21.26
	0.053	-0.03	-0.53	
3				-2.94
	0.053	0.05	0.91	
4				7.04
	0.053	-0.01	-0.16	
5				-32.87
	0.032	-0.03	-0.31	
6				0.71
	0.053	-0.01	-0.13	
7				-3.14
	0.053	-0.05	-0.94	
8				11.99
	0.021	0.01	0.50	
9				-53.59
	0.021	-0.06	-2.91	
10				-57.41
	0.053	-0.04	-0.70	
11				-30.10
	0.053	-0.21	-4.02	
12				-80.00
	0.042	-0.21	-4.90	
13				24.82
	0.053	-0.15	-2.85	
14				126.87
	0.032	0.03	1.09	
15				54.48
	0.032	-0.02	-0.56	
16				-169.95
	0.021	-0.09	-4.26	
17				160.97
	0.021	0.08	3.67	
18				131.42
	0.021	-0.03	-1.50	
19				151.11
	0.021	0.04	1.67	
20				

ANGULAR KINEMATICS : L. THIGH SUBJECT 3 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.105	-0.50	-4.75	
2				49.65
	0.053	-0.04	-0.83	
3				51.82
	0.053	-0.03	-0.66	
4				52.50
	0.053	0.10	1.92	
5				47.20
	0.032	0.06	1.81	
6				0.39
	0.053	0.10	1.96	
7				2.76
	0.053	0.10	1.93	
8				3.04
	0.021	0.04	2.12	
9				45.51
	0.021	0.08	3.60	
10				119.53
	0.053	0.24	4.63	
11				54.73
	0.053	0.29	5.61	
12				-150.53
	0.042	-0.14	-3.27	
13				-363.81
	0.053	-0.61	-11.58	
14				-291.69
	0.032	-0.54	-17.06	
15				157.40
	0.032	-0.16	-4.97	
16				534.16
	0.021	-0.00	-0.23	
17				-13.53
	0.021	-0.11	-5.32	
18				-239.81
	0.021	-0.13	-6.32	
19				-143.38
	0.021	-0.20	-9.34	
20				

ANGULAR KINEMATICS : L.LOWER LEG SUBJECT 3 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.105	-0.45	-4.25	
2				-44.60
	0.053	-0.41	-7.76	
3				-21.12
	0.053	-0.31	-5.91	
4				106.99
	0.053	-0.11	-2.14	
5				180.38
	0.032	0.11	3.59	
6				156.55
	0.053	0.23	4.43	
7				-17.59
	0.053	0.15	2.35	
8				-0.10
	0.021	0.09	4.43	
9				-1.85
	0.021	0.06	2.78	
10				-114.66
	0.053	0.11	2.02	
11				30.07
	0.053	0.20	3.89	
12				91.79
	0.042	0.29	6.84	
13				10.99
	0.053	0.23	4.41	
14				-480.26
	0.032	-0.50	-15.85	
15				-743.10
	0.032	-0.85	-27.01	
16				-621.44
	0.021	-0.74	-35.43	
17				143.47
	0.021	-0.49	-23.25	
18				1058.81
	0.021	-0.23	-13.19	
19				231.06
	0.021	-0.18	-8.34	
20				

ANGULAR KINEMATICS : L. FOOT SUBJECT 3 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.105	-0.99	-9.41	
2				74.94
	0.053	-0.18	-3.51	
3				-7.57
	0.053	-0.53	-10.01	
4				58.97
	0.053	-0.02	-0.42	
5				325.18
	0.032	0.22	7.06	
6				64.85
	0.053	0.12	2.31	
7				-90.90
	0.053	0.17	3.24	
8				-92.72
	0.021	-0.05	-2.56	
9				81.06
	0.021	0.13	6.22	
10				181.56
	0.053	0.07	1.25	
11				14.78
	0.053	0.36	6.77	
12				417.68
	0.042	0.97	23.18	
13				-34.81
	0.053	0.27	5.12	
14				-753.12
	0.032	-0.39	-12.40	
15				-872.95
	0.032	-0.99	-31.54	
16				-716.01
	0.021	-0.73	-34.96	
17				998.48
	0.021	-0.11	-5.33	
18				687.35
	0.021	-0.43	-20.51	
19				452.38
	0.021	-0.23	-11.01	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 3 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	0.04	0.81	
2				-26.54
	0.053	-0.03	-0.58	
3				-28.94
	0.053	-0.04	-0.71	
4				26.54
	0.053	0.04	0.81	
5				28.29
	0.032	0.02	0.77	
6				7.44
	0.021	0.02	1.12	
7				-15.95
	0.053	0.02	0.36	
8				10.27
	0.032	0.05	1.50	
9				-4.61
	0.053	0.01	0.16	
10				-39.03
	0.053	-0.01	-0.14	
11				45.37
	0.053	0.13	2.54	
12				43.94
	0.063	0.14	2.17	
13				8.32
	0.053	0.16	3.02	
14				-41.04
	0.042	-0.01	-0.20	
15				-84.30
	0.021	-0.02	-0.96	
16				43.46
	0.021	0.02	1.16	
17				50.28
	0.021	0.00	0.10	
18				-287.93
	0.021	-0.10	-4.88	
19				154.38
	0.021	-0.03	-1.64	
20				

ANGULAR KINEMATICS : R. THIGH SUBJECT 3 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	0.21	3.98	
2				-1.77
	0.053	0.20	3.89	
3				16.85
	0.053	0.26	4.86	
4				-64.18
	0.053	0.03	0.52	
5				-120.02
	0.032	-0.05	-1.44	
6				-76.05
	0.021	-0.06	-2.68	
7				34.50
	0.053	-0.03	-0.53	
8				-10.04
	0.032	-0.10	-3.05	
9				-98.91
	0.053	-0.25	-4.69	
10				-81.91
	0.053	-0.34	-6.49	
11				-28.81
	0.053	-0.33	-6.20	
12				155.41
	0.063	0.11	1.67	
13				300.72
	0.053	0.59	11.17	
14				273.66
	0.042	0.73	17.48	
15				-176.55
	0.021	0.06	2.83	
16				-639.74
	0.021	-0.06	-2.68	
17				416.44
	0.021	0.24	11.57	
18				500.16
	0.021	0.16	7.83	
19				99.50
	0.021	0.21	9.92	
20				

ANGULAR KINEMATICS : R.LOWER LEG SUBJECT 3 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	-0.03	-0.60	
2				197.60
	0.053	0.51	9.77	
3				224.82
	0.053	0.59	11.20	
4				-73.71
	0.053	0.31	5.90	
5				-233.83
	0.032	-0.03	-1.08	
6				-278.97
	0.021	-0.12	-5.82	
7				-150.39
	0.053	-0.26	-5.02	
8				69.34
	0.032	-0.10	-3.27	
9				51.37
	0.053	-0.15	-2.87	
10				33.23
	0.053	-0.10	-1.87	
11				-1.16
	0.053	-0.15	-2.93	
12				-133.04
	0.063	-0.56	-8.86	
13				27.73
	0.053	-0.07	-1.33	
14				506.51
	0.042	0.86	20.40	
15				704.74
	0.021	0.67	31.97	
16				540.25
	0.021	0.79	37.41	
17				-650.01
	0.021	0.38	18.32	
18				-1114.85
	0.021	0.29	14.00	
19				-293.24
	0.021	0.16	7.84	
20				

ANGULAR KINEMATICS : R. FOOT SUBJECT 3 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	0.17	3.29	
2				321.81
	0.053	1.06	20.19	
3				-50.34
	0.053	0.03	0.65	
4				-116.02
	0.053	0.74	14.10	
5				-83.04
	0.032	-0.12	-3.71	
6				-499.46
	0.021	-0.14	-6.88	
7				-71.85
	0.053	-0.29	-5.59	
8				58.62
	0.032	-0.15	-4.72	
9				160.19
	0.053	0.06	1.13	
10				125.85
	0.053	0.03	0.56	
11				-191.32
	0.053	-0.47	-8.91	
12				-407.15
	0.063	-1.31	-20.81	
13				26.69
	0.053	-0.39	-7.37	
14				771.66
	0.042	1.00	23.75	
15				1007.61
	0.021	0.85	40.24	
16				37.36
	0.021	0.52	24.93	
17				-257.40
	0.021	0.73	34.84	
18				-364.60
	0.021	0.36	17.27	
19				-405.96
	0.021	0.18	8.74	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 4 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.042	0.00	0.10	
2				15.35
	0.042	0.03	0.75	
3				-16.37
	0.042	-0.02	-0.58	
4				-74.18
	0.042	-0.10	-2.37	
5				21.41
	0.042	0.01	0.31	
6				9.40
	0.042	-0.08	-1.97	
7				-48.68
	0.053	-0.09	-1.73	
8				30.14
	0.053	-0.03	-0.55	
9				54.94
	0.032	0.04	1.16	
10				-44.69
	0.053	-0.13	-2.43	
11				-97.59
	0.053	-0.15	-2.94	
12				-18.45
	0.032	-0.11	-3.40	
13				33.85
	0.074	-0.11	-1.52	
14				32.74
	0.035	-0.06	-1.68	
15				1.34
	0.032	-0.05	-1.45	
16				-68.21
	0.021	-0.08	-3.95	
17				223.12
	0.021	0.09	4.41	
18				130.94
	0.021	-0.03	-1.20	
19				-2.39
	0.021	-0.03	-1.25	
20				

ANGULAR KINEMATICS : R. THIGH SUBJECT 4 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.042	-0.11	-2.69	
2				197.57
	0.042	0.24	5.61	
3				256.59
	0.042	0.34	8.09	
4				-56.36
	0.042	0.14	3.25	
5				-217.61
	0.042	-0.04	-1.05	
6				-160.18
	0.042	-0.15	-3.48	
7				-107.47
	0.053	-0.29	-5.56	
8				-34.52
	0.053	-0.27	-5.11	
9				-24.27
	0.032	-0.22	-6.84	
10				89.00
	0.053	-0.07	-1.37	
11				153.44
	0.053	-0.02	-0.39	
12				103.82
	0.032	0.13	4.08	
13				2.58
	0.074	-0.02	-0.28	
14				-71.18
	0.035	0.01	0.34	
15				-0.08
	0.032	-0.01	-0.29	
16				164.08
	0.021	0.12	5.80	
17				164.34
	0.021	0.08	4.03	
18				-123.74
	0.021	0.07	3.20	
19				-44.32
	0.021	0.05	2.27	
20				

ANGULAR KINEMATICS : R.LOWER LEG SUBJECT 4 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.042	0.23	5.51	
2				-135.58
	0.042	-0.01	-0.18	
3				-170.49
	0.042	-0.07	-1.65	
4				22.52
	0.042	0.03	0.76	
5				77.53
	0.042	0.07	1.61	
6				120.47
	0.042	0.24	5.82	
7				-21.13
	0.053	0.04	0.72	
8				-246.99
	0.053	-0.31	-5.85	
9				-212.98
	0.032	-0.33	-10.47	
10				-131.37
	0.053	-0.60	-11.37	
11				106.63
	0.053	-0.31	-5.99	
12				206.54
	0.032	-0.02	-0.52	
13				239.33
	0.074	0.30	4.06	
14				129.68
	0.035	0.22	6.28	
15				-104.14
	0.032	-0.05	-1.59	
16				-167.04
	0.021	0.02	0.73	
17				33.08
	0.021	-0.02	-0.72	
18				-7.69
	0.021	0.01	0.57	
19				62.15
	0.021	0.04	1.87	
20				

ANGULAR KINEMATICS : R. FOOT SUBJECT 4 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.042	0.02	0.37	
2				-25.87
	0.042	-0.03	-0.72	
3				149.80
	0.042	0.28	6.66	
4				62.27
	0.042	0.08	1.90	
5				118.65
	0.042	0.49	11.64	
6				54.81
	0.042	0.18	4.20	
7				-321.19
	0.053	-0.10	-1.85	
8				-214.11
	0.053	-0.31	-5.92	
9				-275.96
	0.032	-0.51	-16.34	
10				-158.02
	0.053	-0.66	-12.56	
11				243.24
	0.053	-0.32	-6.13	
12				417.05
	0.032	0.29	9.33	
13				251.51
	0.074	0.33	4.44	
14				-94.01
	0.035	0.15	4.40	
15				-101.96
	0.032	-0.03	-1.10	
16				-211.06
	0.021	-0.05	-2.62	
17				68.26
	0.021	0.01	0.70	
18				206.12
	0.021	0.04	1.71	
19				-163.86
	0.021	-0.04	-1.73	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 4 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.064	-0.03	-0.42	
2				-18.43
	0.064	-0.10	-1.59	
3				11.63
	0.064	0.02	0.32	
4				32.37
	0.042	0.02	0.47	
5				17.33
	0.021	0.03	1.23	
6				-9.80
	0.053	0.01	0.16	
7				29.10
	0.042	0.10	2.30	
8				23.42
	0.053	0.07	1.27	
9				-19.20
	0.042	0.06	1.40	
10				-1.12
	0.042	0.05	1.21	
11				56.38
	0.042	0.16	3.76	
12				30.09
	0.032	0.08	2.48	
13				-38.15
	0.053	0.12	2.36	
14				-58.34
	0.042	0.00	0.03	
15				16.15
	0.032	0.10	3.13	
16				26.46
	0.021	0.02	1.00	
17				-152.58
	0.021	-0.02	-0.88	
18				-95.69
	0.021	-0.02	-1.01	
19				-75.42
	0.021	-0.05	-2.60	
20				

ANGULAR KINEMATICS : R. THIGH SUBJECT 4 PRE

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.064	0.35	5.55	
2				-22.61
	0.064	0.26	4.11	
3				-91.58
	0.064	-0.02	-0.27	
4				-91.62
	0.042	-0.07	-1.70	
5				-99.48
	0.021	-0.12	-5.51	
6				-96.32
	0.053	-0.25	-4.74	
7				58.68
	0.042	-0.14	-3.36	
8				4.21
	0.053	-0.24	-4.54	
9				-48.16
	0.042	-0.24	-5.63	
10				-16.09
	0.042	-0.22	-5.30	
11				168.31
	0.042	0.06	1.44	
12				224.67
	0.032	0.13	4.14	
13				218.87
	0.053	0.50	9.48	
14				288.47
	0.042	0.68	16.25	
15				-92.02
	0.032	0.16	5.13	
16				-426.29
	0.021	0.01	0.59	
17				-183.27
	0.021	0.01	0.32	
18				215.10
	0.021	0.11	5.10	
19				307.65
	0.021	0.24	11.56	
20				

ANGULAR KINEMATICS : R.LOWER LEG SUBJECT 4 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.064	0.08	1.19	
2				77.41
	0.064	0.39	6.10	
3				72.31
	0.064	0.37	5.78	
4				-60.74
	0.042	0.09	2.25	
5				-141.51
	0.021	-0.04	-1.68	
6				-161.58
	0.053	-0.15	-2.84	
7				-19.03
	0.042	-0.10	-2.38	
8				30.67
	0.053	-0.07	-1.39	
9				36.54
	0.042	-0.03	-0.66	
10				-7.77
	0.042	-0.07	-1.76	
11				-207.05
	0.042	-0.39	-9.35	
12				-265.72
	0.032	-0.41	-12.92	
13				171.58
	0.053	-0.16	-3.05	
14				701.76
	0.042	0.70	16.55	
15				608.04
	0.032	0.81	25.68	
16				387.65
	0.021	0.65	30.80	
17				-7.68
	0.021	0.54	25.48	
18				-717.03
	0.021	0.33	15.74	
19				-547.72
	0.021	0.09	4.24	
20				

ANGULAR KINEMATICS : R. FOOT SUBJECT 4 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.064	0.36	5.62	
2				33.28
	0.064	0.49	7.74	
3				-29.97
	0.064	0.24	3.72	
4				-123.75
	0.042	-0.01	-0.12	
5				-52.04
	0.021	0.02	0.98	
6				37.45
	0.053	0.06	1.06	
7				-176.85
	0.042	-0.23	-5.52	
8				8.23
	0.053	0.08	1.45	
9				8.38
	0.042	-0.22	-5.13	
10				-168.01
	0.042	-0.27	-6.49	
11				-222.31
	0.042	-0.61	-14.46	
12				-229.33
	0.032	-0.51	-16.12	
13				203.83
	0.053	-0.37	-6.97	
14				850.90
	0.042	0.82	19.62	
15				734.49
	0.032	0.87	27.73	
16				583.75
	0.021	0.86	41.07	
17				-246.93
	0.021	0.45	21.25	
18				-1013.78
	0.021	0.42	19.78	
19				-519.74
	0.021	0.19	8.86	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 5 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	0.09	1.78	
2				-33.07
	0.053	0.00	0.05	
3				-44.05
	0.053	-0.03	-0.53	
4				-14.48
	0.084	-0.06	-0.71	
5				-6.73
	0.053	-0.05	-0.99	
6				-1.41
	0.084	-0.07	-0.81	
7				0.72
	0.032	-0.03	-0.94	
8				-12.45
	0.042	-0.06	-1.53	
9				-15.73
	0.053	-0.08	-1.52	
10				-38.19
	0.053	-0.18	-3.33	
11				-19.91
	0.042	-0.11	-2.57	
12				-102.83
	0.032	-0.26	-8.19	
13				-0.83
	0.042	-0.11	-2.60	
14				204.87
	0.042	-0.03	-0.66	
15				22.48
	0.032	-0.05	-1.65	
16				41.44
	0.032	0.03	0.86	
17				67.69
	0.021	0.01	0.48	
18				72.41
	0.021	0.06	2.76	
19				-84.39
	0.021	0.02	0.99	
20				

ANGULAR KINEMATICS : L. THIGH SUBJECT 5 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	-0.13	-2.49	
2				2.39
	0.053	-0.12	-2.36	
3				27.59
	0.053	-0.05	-1.04	
4				39.08
	0.084	-0.03	-0.31	
5				34.75
	0.053	0.07	1.33	
6				38.16
	0.084	0.19	2.30	
7				-3.69
	0.032	0.03	1.08	
8				26.10
	0.042	0.16	3.80	
9				107.89
	0.053	0.26	5.05	
10				-20.37
	0.053	0.15	2.84	
11				-114.01
	0.042	-0.04	-0.94	
12				-175.71
	0.032	-0.17	-5.46	
13				-323.08
	0.042	-0.54	-12.81	
14				-204.59
	0.042	-0.55	-12.98	
15				102.90
	0.032	-0.27	-8.49	
16				326.49
	0.032	-0.03	-0.98	
17				140.32
	0.021	-0.09	-4.07	
18				-153.80
	0.021	-0.11	-5.02	
19				-20.50
	0.021	-0.11	-5.45	
20				

ANGULAR KINEMATICS : L.LOWER LEG SUBJECT 5 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	-0.29	-5.57	
2				-15.06
	0.053	-0.33	-6.37	
3				-23.21
	0.053	-0.36	-6.79	
4				106.04
	0.084	-0.07	-0.80	
5				160.70
	0.053	0.22	4.17	
6				69.71
	0.084	0.33	3.96	
7				-9.67
	0.032	0.11	3.51	
8				-13.17
	0.042	0.13	3.20	
9				-35.28
	0.053	0.12	2.22	
10				-16.06
	0.053	0.13	2.44	
11				34.75
	0.042	0.17	4.04	
12				123.89
	0.032	0.26	8.29	
13				-68.51
	0.042	0.06	1.52	
14				-708.21
	0.042	-0.74	-17.73	
15				-664.21
	0.032	-0.83	-26.37	
16				-291.25
	0.032	-0.90	-28.44	
17				261.52
	0.021	-0.38	-18.13	
18				557.40
	0.021	-0.29	-13.80	
19				498.19
	0.021	-0.07	-3.34	
20				

ANGULAR KINEMATICS : L. FOOT SUBJECT 5 NONPREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.053	-0.46	-8.72	
2				-6.29
	0.053	-0.48	-9.05	
3				25.55
	0.053	-0.39	-7.38	
4				166.76
	0.084	-0.03	-0.30	
5				149.72
	0.053	0.15	2.84	
6				40.60
	0.084	0.21	2.47	
7				-22.09
	0.032	0.04	1.33	
8				35.15
	0.042	0.19	4.50	
9				164.42
	0.053	0.39	7.37	
10				31.44
	0.053	0.31	5.99	
11				167.42
	0.042	0.68	16.16	
12				131.47
	0.032	0.38	12.20	
13				-379.73
	0.042	0.09	2.21	
14				-828.37
	0.042	-0.77	-18.24	
15				-790.32
	0.032	-0.98	-30.99	
16				-287.18
	0.032	-0.91	-28.80	
17				333.03
	0.021	-0.43	-20.50	
18				638.22
	0.021	-0.25	-12.04	
19				323.31
	0.021	-0.11	-5.25	
20				

ANGULAR KINEMATICS : TRUNK SUBJECT 5 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.084	-0.09	-1.11	
2				31.71
	0.084	0.13	1.56	
3				1.33
	0.021	-0.02	-1.00	
4				-6.33
	0.032	0.04	1.22	
5				66.75
	0.042	0.03	0.76	
6				-46.69
	0.042	-0.02	-0.49	
7				6.50
	0.063	0.06	1.03	
8				50.36
	0.042	0.09	2.15	
9				-5.03
	0.042	0.03	0.77	
10				-9.30
	0.042	0.07	1.76	
11				61.12
	0.042	0.14	3.33	
12				29.66
	0.042	0.13	3.01	
13				10.40
	0.042	0.16	3.77	
14				-87.08
	0.032	-0.02	-0.65	
15				-85.07
	0.032	0.02	0.64	
16				84.88
	0.021	0.04	2.02	
17				-68.71
	0.021	-0.02	-1.16	
18				-66.21
	0.021	0.01	0.63	
19				-194.51
	0.021	-0.07	-3.45	
20				

ANGULAR KINEMATICS : R. THIGH SUBJECT 5 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.084	0.31	3.74	
2				-54.17
	0.084	-0.07	-0.81	
3				-59.62
	0.021	-0.03	-1.27	
4				-36.46
	0.032	-0.09	-2.73	
5				-23.73
	0.042	-0.08	-1.89	
6				-13.57
	0.042	-0.14	-3.23	
7				4.84
	0.063	-0.11	-1.69	
8				-23.42
	0.042	-0.19	-4.46	
9				-55.91
	0.042	-0.19	-4.63	
10				19.81
	0.042	-0.15	-3.62	
11				90.75
	0.042	-0.03	-0.81	
12				239.90
	0.042	0.27	6.45	
13				253.45
	0.042	0.41	9.83	
14				28.92
	0.032	0.24	7.67	
15				186.39
	0.032	0.53	16.68	
16				-173.61
	0.021	0.05	2.20	
17				-608.70
	0.021	0.01	0.70	
18				144.05
	0.021	0.11	5.22	
19				144.71
	0.021	0.17	8.26	
20				

ANGULAR KINEMATICS : R.LOWER LEG SUBJECT 5 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.084	0.57	6.76	
2				-18.29
	0.084	0.44	5.23	
3				-55.73
	0.021	0.04	2.08	
4				-144.28
	0.032	-0.07	-2.35	
5				-210.37
	0.042	-0.14	-3.44	
6				-19.80
	0.042	-0.13	-3.08	
7				-2.23
	0.063	-0.22	-3.53	
8				16.19
	0.042	-0.09	-2.23	
9				55.11
	0.042	-0.03	-0.64	
10				-10.74
	0.042	-0.11	-2.68	
11				-157.58
	0.042	-0.30	-7.26	
12				-139.08
	0.042	-0.36	-8.52	
13				214.03
	0.042	0.07	1.73	
14				552.90
	0.032	0.46	14.70	
15				655.92
	0.032	0.81	25.84	
16				551.06
	0.021	0.67	32.06	
17				-96.31
	0.021	0.49	23.31	
18				-850.03
	0.021	0.30	14.21	
19				-267.54
	0.021	0.18	8.59	
20				

ANGULAR KINEMATICS : R. FOOT SUBJECT 5 PREF

FRAME#	TIME	DISPLACEMENT rad	VELOCITY rad/sec	ACCELERATION rad/sec/sec
1				
	0.084	0.67	7.98	
2				-24.74
	0.084	0.50	5.90	
3				31.03
	0.021	0.22	10.58	
4				-306.32
	0.032	-0.32	-10.18	
5				-204.82
	0.042	0.22	5.21	
6				216.01
	0.042	-0.09	-2.25	
7				-226.71
	0.063	-0.27	-4.32	
8				17.22
	0.042	-0.06	-1.34	
9				16.82
	0.042	-0.14	-3.43	
10				-306.46
	0.042	-0.60	-14.21	
11				-138.89
	0.042	-0.39	-9.27	
12				77.04
	0.042	-0.46	-10.98	
13				194.54
	0.042	-0.05	-1.10	
14				596.20
	0.032	0.44	14.06	
15				714.10
	0.032	0.79	25.15	
16				410.28
	0.021	0.57	26.99	
17				-163.46
	0.021	0.44	20.86	
18				-173.24
	0.021	0.49	23.35	
19				-743.02
	0.021	0.16	7.75	
20				

APPENDIX B

LINEAR VELOCITY DATA

LINEAR VELOCITY DISTAL END POINTS FOR THIGH, LEG & FOOT.

IN m/sec FOR THE LEFT SIDE: SUBJECT 0 NONPREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	1.11	2.37	3.48	4.51
2	1.52	1.92	3.57	4.51
3	1.22	2.26	4.23	5.03
4	1.10	2.16	3.75	4.28
5	1.63	2.25	3.24	3.61
6	1.85	2.41	2.16	2.09
7	2.67	2.13	0.52	1.04
8	2.11	2.05	0.34	0.41
9	3.57	1.26	0.05	0.17
10	3.31	0.60	0.45	0.29
11	4.39	1.74	1.71	0.34
12	4.70	4.93	4.71	3.53
13	3.83	9.17	8.16	8.41
14	1.72	9.18	15.06	21.87
15	3.54	2.69	19.07	30.09
16	2.79	3.05	17.85	25.76
17	2.79	4.33	13.64	16.80
18	2.09	6.75	10.65	15.03
19	1.89	6.74	9.76	10.51

LINEAR VELOCITY DISTAL END POINTS FOR THIGH,LEG & FOOT.

IN m/sec FOR THE RIGHT SIDE: SUBJECT 0 PREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	1.56	2.65	4.63	5.80
2	1.79	2.52	4.30	5.74
3	1.62	2.23	3.85	4.20
4	3.03	3.44	1.55	1.51
5	3.12	2.83	0.98	1.58
6	2.73	1.90	0.24	0.39
7	2.60	1.21	0.66	0.60
8	3.28	1.23	0.44	0.49
9	4.34	0.56	0.58	0.09
10	4.18	1.67	0.95	0.38
11	4.46	2.96	2.60	1.08
12	5.55	7.82	5.37	4.51
13	5.74	8.26	10.00	9.31
14	4.75	10.55	11.64	9.24
15	4.11	10.30	16.78	22.69
16	1.37	2.05	22.99	34.78
17	2.53	5.14	17.90	21.01
18	4.42	7.12	12.71	15.15
19	0.31	7.76	10.55	10.03

LINEAR VELOCITY DISTAL END POINTS FOR THIGH, LEG & FOOT.

IN m/sec FOR THE LEFT SIDE: SUBJECT 1 NONPREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	2.23	2.81	4.40	4.60
2	2.82	2.65	2.43	1.98
3	3.39	3.26	0.46	1.41
4	2.22	2.27	0.55	0.50
5	3.13	1.92	0.34	0.11
6	2.39	1.14	0.34	0.17
7	3.58	0.48	0.04	0.69
8	4.07	1.15	1.20	0.37
9	3.37	2.41	1.94	1.18
10	3.26	3.11	2.94	2.78
11	4.47	5.32	5.51	5.15
12	3.12	8.63	8.31	7.97
13	4.16	8.98	10.69	12.49
14	2.08	9.41	10.96	15.79
15	1.25	5.68	14.81	20.83
16	3.57	1.83	15.98	22.54
17	1.27	2.82	11.68	16.58
18	1.71	2.46	10.31	15.50
19	4.37	5.09	8.07	12.08

LINEAR VELOCITY DISTAL END POINTS FOR THIGH,LEG & FOOT.

IN m/sec FOR THE RIGHT SIDE: SUBJECT 1 PREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	1.24	3.10	4.86	5.86
2	1.41	2.08	4.86	5.34
3	2.13	2.42	3.15	3.06
4	3.98	2.82	1.60	0.80
5	4.08	2.61	1.87	1.62
6	2.52	2.28	0.32	0.70
7	2.88	1.51	0.35	0.35
8	3.23	1.08	0.27	0.34
9	3.57	1.55	1.26	0.65
10	4.47	1.55	1.95	0.62
11	3.93	3.67	3.28	2.90
12	5.04	6.89	6.32	5.74
13	4.62	8.86	9.03	8.42
14	1.46	10.81	11.45	12.65
15	3.71	9.08	13.87	19.81
16	1.36	3.28	17.59	25.50
17	1.09	2.16	13.97	20.56
18	1.78	2.74	11.07	16.64
19	1.16	5.59	9.55	11.38

LINEAR VELOCITY DISTAL END POINTS FOR THIGH,LEG & FOOT.

IN m/sec FOR THE RIGHT SIDE: SUBJECT 2 [illegible]

FRAME#	HIP	KNEE	ANKLE	TOE
1	1.61	4.06	4.64	5.52
2	1.64	3.36	5.30	6.51
3	2.73	3.21	5.61	6.78
4	2.28	3.16	5.05	6.00
5	2.70	3.13	2.83	2.59
6	4.11	2.90	0.77	0.97
7	3.22	2.31	0.50	0.36
8	3.25	2.18	0.00	0.77
9	2.81	1.73	0.13	1.09
10	4.47	0.88	0.57	0.53
11	4.23	1.53	1.89	0.55
12	4.62	3.46	3.22	1.08
13	5.09	7.44	7.13	6.44
14	3.40	9.76	9.66	9.49
15	4.07	8.97	15.82	22.21
16	2.54	3.49	10.01	23.09
17	1.15	4.92	12.79	15.70
18	4.60	5.96	10.27	12.82
19	1.99	6.19	8.58	[illegible].04

LINEAR VELOCITY DISTAL END POINTS FOR THIGH,LEG & FOOT.

IN m/sec FOR THE LEFT SIDE: SUBJECT 2 PREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	1.21	2.52	3.71	4.97
2	0.14	2.32	4.31	5.39
3	1.67	2.18	4.72	5.43
4	2.02	2.13	4.00	3.92
5	2.51	2.42	2.51	2.54
6	2.58	3.36	1.27	1.26
7	2.68	2.28	0.41	0.72
8	3.29	2.10	0.80	0.91
9	2.61	1.50	0.06	0.10
10	4.16	1.18	0.74	0.55
11	3.35	1.49	1.13	0.03
12	4.79	4.66	3.93	2.03
13	4.72	8.04	7.97	7.78
14	3.58	9.46	9.21	9.36
15	2.65	9.22	14.31	18.53
16	1.30	2.60	16.21	24.07
17	1.77	3.83	11.39	16.19
18	2.76	5.10	9.09	10.59
19	2.49	5.39	6.70	9.18

LINEAR VELOCITY DISTAL END POINTS FOR THIGH,LEG & FOOT.

IN m/sec FOR THE LEFT SIDE: SUBJECT 3 NONPREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	1.72	3.83	4.89	6.41
2	2.45	2.97	5.65	5.99
3	2.27	3.15	5.75	6.37
4	3.03	2.67	3.60	3.59
5	3.52	2.60	0.99	2.06
6	2.50	2.36	0.38	0.85
7	3.37	1.50	0.55	0.43
8	1.99	2.33	0.73	0.27
9	4.05	0.21	1.14	0.46
10	3.45	1.19	0.63	0.94
11	4.75	2.35	1.31	0.82
12	5.51	6.11	5.25	2.58
13	3.93	9.32	8.70	7.33
14	1.75	10.48	11.66	14.74
15	3.10	7.09	15.71	24.06
16	4.36	3.24	18.77	26.07
17	1.30	3.25	14.27	14.68
18	3.59	4.69	10.61	15.28
19	0.72	4.80	8.56	10.42

LINEAR VELOCITY DISTAL END POINTS FOR THIGH, LEG & FOOT.

IN m/sec FOR THE RIGHT SIDE: SUBJECT 3 PREF

FRAME#	HIP	KNEE	ANKLE	TOE
1				
	2.85	3.79	4.90	5.93
2				
	2.43	4.25	5.17	7.27
3				
	2.08	3.63	8.36	8.47
4				
	3.23	3.17	5.43	6.24
5				
	2.70	2.91	2.41	2.52
6				
	3.39	2.57	0.20	2.58
7				
	3.08	2.59	0.64	0.97
8				
	3.07	1.83	0.51	0.75
9				
	3.16	1.18	0.24	0.30
10				
	2.71	0.99	0.44	0.26
11				
	4.35	1.91	1.09	0.54
12				
	4.59	5.35	4.44	2.16
13				
	4.18	8.43	7.93	7.77
14				
	1.87	9.28	12.32	16.41
15				
	3.11	5.15	16.85	28.36
16				
	3.16	3.22	17.35	21.51
17				
	4.30	4.10	11.48	20.50
18				
	1.31	3.90	9.79	14.47
19				
	1.73	4.49	7.75	8.52

LINEAR VELOCITY DISTAL END POINTS FOR THIGH,LEG & FOOT.

IN m/sec FOR THE LEFT SIDE: SUBJECT 4 NONPREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	2.86	5.11	6.03	7.86
2	1.89	4.72	6.11	8.18
3	3.04	3.63	6.80	8.13
4	4.67	3.68	5.34	6.10
5	2.63	2.35	3.10	2.10
6	4.19	1.69	0.84	0.37
7	4.48	1.46	0.27	0.10
8	3.61	1.07	0.48	0.49
9	2.65	1.30	0.24	0.99
10	4.27	2.23	1.57	0.51
11	4.89	4.39	3.97	1.30
12	5.65	7.35	5.02	5.96
13	2.69	8.84	9.69	10.10
14	3.10	7.17	11.47	18.46
15	2.20	5.90	15.10	19.67
16	4.38	3.06	15.11	18.74
17	1.16	3.13	11.53	14.68
18	1.87	5.63	9.31	14.50
19	3.10	4.93	8.50	7.99

LINEAR VELOCITY DISTAL END POINTS FOR THIGH,LEG & FOOT.

IN m/sec FOR THE RIGHT SIDE: SUBJECT 4 PREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	1.93	5.13	5.15	6.72
2	1.47	4.66	6.64	7.91
3	3.17	3.31	5.74	6.98
4	3.77	2.31	3.47	3.37
5	3.27	3.31	2.06	1.48
6	3.10	1.44	0.61	0.63
7	5.03	1.21	0.32	1.75
8	4.12	0.87	0.24	0.63
9	4.30	1.04	1.18	0.52
10	3.88	2.10	1.73	0.88
11	5.64	5.43	3.74	2.57
12	4.95	7.85	6.67	7.24
13	4.02	9.06	9.26	8.66
14	1.81	11.30	12.41	16.71
15	3.88	7.29	17.72	25.91
16	3.12	2.71	19.32	30.63
17	1,97	2.97	16.54	22.15
18	1.01	4.07	12.52	17.73
19	0.69	6.49	9.02	11.83

LINEAR VELOCITY DISTAL END POINTS FOR THIGH, LEG & FOOT.

IN m/sec FOR THE LEFT SIDE: SUBJECT 5 NONPREF

FRAME#	HIP	KNEE	ANKLE	TOE
1	2.22	3.83	5.84	7.17
2	2.66	3.63	6.01	7.39
3	2.44	3.19	6.40	7.05
4	3.18	3.23	3.62	3.56
5	2.87	2.18	0.25	1.06
6	3.26	2.26	0.48	0.62
7	2.93	1.67	0.23	0.71
8	4.16	1.66	0.66	1.32
9	3.44	1.33	1.30	0.83
10	4.22	2.58	1.87	0.80
11	3.80	5.34	4.52	1.10
12	6.82	6.80	7.09	6.99
13	3.44	9.58	9.13	8.82
14	2.08	9.69	11.66	15.59
15	2.57	6.30	14.71	22.32
16	1.64	2.00	15.64	21.08
17	1.51	2.61	11.57	16.03
18	1.99	4.02	9.30	11.50
19	2.16	4.13	5.95	6.99

LINEAR VELOCITY DISTAL END POINTS FOR THIGH, LEG & FOOT.

IN m/sec FOR THE RIGHT SIDE: SUBJECT 5 PREF

FRAME#	HIP	KNEE	ANKLE	TOE
1				
	1.70	3.88	5.67	6.78
2				
	3.64	2.99	5.46	5.83
3				
	1.63	2.20	3.19	6.42
4				
	3.56	2.77	1.66	2.81
5				
	3.25	2.32	0.55	1.19
6				
	2.60	1.95	0.44	1.38
7				
	3.49	1.68	0.11	1.09
8				
	4.20	1.21	0.24	0.75
9				
	3.48	1.10	1.37	0.65
10				
	4.19	2.47	1.73	1.60
11				
	4.38	4.51	3.88	1.76
12				
	3.84	7.10	7.06	6.34
13				
	4.78	9.46	9.36	8.12
14				
	1.74	7.35	11.24	15.07
15				
	2.22	10.26	16.02	22.60
16				
	5.05	3.78	19.96	26.45
17				
	1.71	2.80	14.42	20.18
18				
	1.75	3.17	10.58	16.00
19				
	0.65	4.64	8.55	9.87

APPENDIX C

CENTRE OF MASS VELOCITY DATA

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CENTER OF MASS DETERMINATION FOR SUBJECT # 0 - NON PREF

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FRAME#	CM COORDINATES X	Y	DISPLACEMENT Hor.	Ver.	LIN.	VELOCITY Hor.	Ver.	LIN.
1	59.34	34.28						
			-0.08	0.01	0.08	-1.31	0.12	1.32
2	57.69	34.43						
			-0.09	0.02	0.09	-1.44	0.39	1.49
3	55.88	34.92						
			-0.10	-0.01	0.11	-1.66	-0.22	1.68
4	53.79	34.64						
			-0.09	-0.02	0.10	-1.49	-0.26	1.51
5	51.92	34.31						
			-0.10	-0.04	0.11	-1.58	-0.64	1.70
6	49.94	33.51						
			-0.19	-0.05	0.19	-1.79	-0.49	1.85
7	46.19	32.49						
			-0.25	0.03	0.25	-2.39	0.26	2.41
8	41.18	33.04						
			-0.17	-0.00	0.17	-2.70	-0.00	2.70
9	37.79	33.04						
			-0.25	0.01	0.25	-3.42	0.15	3.42
10	32.77	33.26						
			-0.17	-0.00	0.17	-3.18	-0.04	3.18
11	29.44	33.22						
			-0.19	0.03	0.19	-3.57	0.64	3.63
12	25.70	33.89						
			-0.40	-0.00	0.40	-3.80	-0.04	3.80
13	17.75	33.80						
			-0.18	-0.01	0.18	-3.37	-0.27	3.38
14	14.21	33.53						
			-0.13	0.06	0.15	-2.54	1.21	2.81
15	11.55	34.79						
			-0.06	0.02	0.07	-3.05	0.81	3.15
16	10.28	35.13						
			-0.02	0.03	0.03	-1.46	2.54	2.93
17	9.97	35.66						
			-0.05	0.03	0.06	-2.46	1.30	2.78
18	8.94	36.20						
			-0.04	0.04	0.05	-1.74	1.86	2.54
19	8.21	36.98						
			-0.04	0.04	0.06	-2.08	1.73	2.71
20	7.34	37.71						

CENTER OF MASS DETERMINATION FOR SUBJECT # 0 - PREF

FRAME#	CM COORDINATES		DISPLACEMENT			VELOCITY		
	X	Y	Hor.	Ver.	LIN.	Hor.	Ver.	LIN.
1	11.04	44.63						
			0.11	-0.01	0.11	1.67	-0.08	1.67
2	13.08	44.53						
			0.11	-0.04	0.11	1.69	-0.63	1.80
3	15.14	43.75						
			0.22	-0.09	0.24	1.77	-0.71	1.90
4	19.43	42.03						
			0.14	-0.01	0.14	2.60	-0.20	2.61
5	22.08	41.82						
			0.21	0.00	0.21	2.79	0.03	2.79
6	26.04	41.86						
			0.22	0.03	0.22	3.03	0.38	3.06
7	30.35	42.40						
			0.10	0.01	0.10	3.02	0.23	3.03
8	32.19	42.54						
			0.18	0.02	0.18	3.42	0.32	3.43
9	35.65	42.86						
			0.19	0.01	0.19	3.69	0.28	3.70
10	39.40	43.14						
			0.20	0.02	0.20	3.72	0.30	3.73
11	43.17	43.45						
			0.19	0.01	0.19	3.67	0.17	3.68
12	46.90	43.62						
			0.22	-0.04	0.22	4.10	-0.69	4.16
13	51.06	42.92						
			0.08	-0.03	0.09	3.89	-1.34	4.11
14	52.64	42.38						
			0.09	-0.01	0.10	4.49	-0.59	4.53
15	54.46	42.14						
			0.31	0.09	0.32	3.69	1.11	3.86
16	60.46	43.95						
			0.04	0.01	0.04	1.85	0.50	1.91
17	61.21	44.15						
			0.05	0.04	0.06	2.25	1.73	2.84
18	62.12	44.85						
			0.05	0.06	0.08	2.39	2.66	3.58
19	63.09	45.93						
			0.03	0.04	0.05	1.67	1.85	2.49
20	63.76	46.68						

CENTER OF MASS DETERMINATION FOR SUBJECT # 1 - NON PREF

FRAME#	CM COORDINATES X	CM COORDINATES Y	DISPLACEMENT Hor.	DISPLACEMENT Ver.	DISPLACEMENT LIN.	VELOCITY Hor.	VELOCITY Ver.	VELOCITY LIN.
1	91.61	29.90						
			-0.06	-0.02	0.07	-2.04	-0.69	2.15
2	90.40	29.49						
			-0.10	-0.01	0.10	-2.39	-0.28	2.41
3	88.52	29.27						
			-0.08	-0.01	0.09	-2.66	-0.47	2.70
4	86.95	29.00						
			-0.13	-0.01	0.13	-2.41	-0.18	2.42
5	84.57	28.82						
			-0.14	-0.02	0.14	-2.69	-0.32	2.71
6	81.92	28.50						
			-0.22	0.00	0.22	-2.65	0.00	2.65
7	77.74	28.50						
			-0.23	0.02	0.23	-3.10	0.26	3.11
8	73.48	28.86						
			-0.18	0.04	0.18	-3.39	0.81	3.49
9	70.14	29.65						
			-0.17	0.02	0.17	-3.22	0.35	3.24
10	66.96	30.00						
			-0.17	-0.01	0.17	-3.18	-0.25	3.19
11	63.83	29.75						
			-0.19	-0.04	0.20	-3.06	-0.58	3.11
12	60.22	29.06						
			-0.22	-0.04	0.23	-3.01	-0.60	3.07
13	56.07	28.23						
			-0.06	0.01	0.06	-2.97	0.33	2.99
14	54.90	28.36						
			-0.05	0.01	0.05	-2.19	0.31	2.21
15	54.04	28.48						
			-0.09	0.03	0.10	-1.77	0.61	1.88
16	52.29	29.08						
			-0.02	0.01	0.02	-1.61	1.32	2.08
17	51.97	29.34						
			-0.03	0.01	0.04	-1.59	0.55	1.69
18	51.34	29.56						
			-0.02	0.02	0.03	-0.89	1.04	1.37
19	50.99	29.97						
			-0.03	0.06	0.06	-1.26	2.68	2.96
20	50.50	31.03						

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CENTER OF MASS DETERMINATION FOR SUBJECT # 1 - PREF

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FRAME#	CM COORDINATES		DISPLACEMENT			VELOCITY		
	X	Y	Hor.	Ver.	LIN.	Hor.	Ver.	LIN.
1	11.21	35.35						
			0.18	0.01	0.18	1.71	0.08	1.71
2	14.30	35.49						
			0.19	-0.04	0.19	1.81	-0.37	1.85
3	17.57	34.82						
			0.22	-0.03	0.22	2.10	-0.30	2.12
4	21.37	34.27						
			0.05	0.01	0.05	2.56	0.41	2.60
5	22.29	34.42						
			0.05	-0.02	0.05	2.36	-0.73	2.47
6	23.15	34.15						
			0.33	0.02	0.33	2.61	0.14	2.62
7	28.81	34.45						
			0.18	0.01	0.18	2.92	0.21	2.92
8	31.97	34.68						
			0.39	0.03	0.39	3.12	0.25	3.13
9	38.74	35.22						
			0.17	0.04	0.18	3.32	0.69	3.39
10	41.74	35.85						
			0.18	0.01	0.18	3.41	0.11	3.41
11	44.82	35.95						
			0.17	0.01	0.17	3.19	0.13	3.19
12	47.71	36.06						
			0.19	-0.06	0.20	3.65	-1.05	3.80
13	51.01	35.11						
			0.14	-0.03	0.15	3.43	-0.73	3.51
14	53.49	34.58						
			0.06	0.02	0.06	2.00	0.49	2.06
15	54.57	34.85						
			0.12	0.04	0.13	2.92	0.96	3.08
16	56.68	35.55						
			0.06	0.02	0.06	1.78	0.64	1.89
17	57.65	35.89						
			0.03	0.03	0.04	1.19	1.39	1.83
18	58.08	36.40						
			0.02	0.03	0.04	1.18	1.42	1.85
19	58.51	36.91						
			0.03	0.04	0.04	1.19	1.70	2.08
20	58.94	37.53						

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CENTER OF MASS DETERMINATION FOR SUBJECT # 2 - NON PREF

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FRAME#	CM COORDINATES		DISPLACEMENT			VELOCITY		
	X	Y	Hor.	Ver.	LIN.	Hor.	Ver.	LIN.
1	20.33	28.90						
			0.14	0.02	0.14	2.17	0.26	2.18
2	22.25	29.13						
			0.14	-0.00	0.14	2.15	-0.07	2.15
3	24.14	29.06						
			0.15	-0.02	0.15	2.37	-0.28	2.38
4	26.23	28.82						
			0.15	-0.04	0.15	2.37	-0.67	2.46
5	28.32	28.23						
			0.22	-0.01	0.22	2.66	-0.13	2.66
6	31.46	28.07						
			0.18	-0.01	0.18	3.42	-0.19	3.42
7	33.97	27.93						
			0.17	-0.01	0.17	3.23	-0.16	3.23
8	36.35	27.81						
			0.10	0.00	0.10	3.28	0.08	3.28
9	37.80	27.85						
			0.13	0.02	0.13	3.09	0.36	3.11
10	39.62	28.06						
			0.23	0.01	0.23	3.72	0.15	3.73
11	42.90	28.19						
			0.23	0.06	0.24	3.71	1.00	3.84
12	46.18	29.07						
			0.22	0.03	0.23	3.55	0.41	3.58
13	49.32	29.44						
			0.17	-0.01	0.17	4.16	-0.13	4.16
14	51.77	29.36						
			0.23	-0.03	0.23	3.67	-0.46	3.70
15	55.01	28.95						
			0.20	0.04	0.20	3.78	0.68	3.84
16	57.79	29.45						
			0.11	0.04	0.11	2.57	0.93	2.73
17	59.30	30.00						
			0.05	0.04	0.07	1.66	1.39	2.17
18	60.03	30.62						
			0.04	0.06	0.07	1.97	2.81	3.43
19	60.61	31.44						
			0.03	0.03	0.05	1.53	1.65	2.25
20	61.06	31.93						

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CENTER OF MASS DETERMINATION FOR SUBJECT # 2 - PREF

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FRAME#	CM COORDINATES X	CM COORDINATES Y	DISPLACEMENT Hor.	DISPLACEMENT Ver.	DISPLACEMENT LIN.	VELOCITY Hor.	VELOCITY Ver.	VELOCITY LIN.
1	97.38	30.07						
			-0.09	0.02	0.09	-1.62	0.34	1.66
2	96.11	30.34						
			-0.06	-0.00	0.06	-1.08	-0.05	1.08
3	95.26	30.31						
			-0.19	-0.03	0.20	-1.85	-0.32	1.87
4	92.35	29.80						
			-0.10	-0.01	0.10	-1.87	-0.21	1.88
5	90.88	29.64						
			-0.21	-0.04	0.21	-2.17	-0.41	2.21
6	87.80	29.05						
			-0.15	-0.02	0.16	-2.45	-0.34	2.48
7	85.48	28.73						
			-0.20	-0.01	0.20	-2.78	-0.19	2.78
8	82.43	28.52						
			-0.06	-0.01	0.06	-2.64	-0.45	2.68
9	81.59	28.38						
			-0.23	-0.00	0.23	-2.74	-0.05	2.74
10	78.15	28.32						
			-0.25	0.00	0.25	-3.39	0.01	3.39
11	74.41	28.33						
			-0.27	0.02	0.27	-3.24	0.29	3.26
12	70.33	28.70						
			-0.26	-0.03	0.26	-3.47	-0.45	3.50
13	66.51	28.20						
			-0.16	-0.02	0.16	-3.74	-0.52	3.78
14	64.15	27.87						
			-0.11	0.00	0.11	-3.36	0.14	3.36
15	62.56	27.94						
			-0.13	0.08	0.16	-2.55	1.50	2.96
16	60.56	29.12						
			-0.07	0.06	0.09	-1.58	1.37	2.09
17	59.56	29.98						
			-0.04	0.02	0.05	-1.81	1.16	2.15
18	58.99	30.35						
			-0.02	0.04	0.04	-1.05	1.86	2.14
19	58.66	30.93						
			-0.04	0.05	0.06	-1.78	2.33	2.93
20	58.10	31.67						

CENTER OF MASS DETERMINATION FOR SUBJECT # 3 - NON PREF

FRAME#	CM COORDINATES X	Y	DISPLACEMENT Hor.	Ver.	LIN.	VELOCITY Hor.	Ver.	LIN.
1	100.75	35.39						
			-0.22	0.04	0.22	-2.07	0.41	2.11
2	96.71	36.19						
			-0.12	0.01	0.12	-2.30	0.28	2.31
3	94.47	36.46						
			-0.14	0.03	0.14	-2.57	0.57	2.64
4	91.96	37.02						
			-0.15	0.01	0.15	-2.88	0.18	2.89
5	89.15	37.20						
			-0.09	-0.01	0.10	-2.99	-0.46	3.03
6	87.40	36.93						
			-0.14	-0.02	0.14	-2.62	-0.42	2.65
7	84.84	36.51						
			-0.16	-0.01	0.16	-2.96	-0.16	2.96
8	81.96	36.36						
			-0.07	0.00	0.07	-3.27	0.14	3.28
9	80.68	36.41						
			-0.07	0.00	0.07	-3.11	0.21	3.11
10	79.47	36.50						
			-0.17	0.00	0.17	-3.19	0.09	3.19
11	76.36	36.58						
			-0.17	-0.00	0.17	-3.32	-0.02	3.32
12	73.12	36.56						
			-0.15	-0.01	0.15	-3.55	-0.22	3.56
13	70.35	36.39						
			-0.18	0.01	0.18	-3.51	0.10	3.51
14	66.93	36.48						
			-0.08	0.03	0.09	-2.62	0.94	2.79
15	65.40	37.04						
			-0.08	0.05	0.09	-2.41	1.64	2.91
16	63.99	38.00						
			-0.06	0.02	0.06	-2.78	1.14	3.01
17	62.90	38.44						
			-0.03	0.02	0.04	-1.26	1.14	1.70
18	62.41	38.89						
			-0.04	0.04	0.06	-1.77	2.06	2.71
19	61.72	39.69						
			-0.03	0.03	0.04	-1.27	1.40	1.89
20	61.22	40.24						

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CENTER OF MASS DETERMINATION FOR SUBJECT # 3 - PREF

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FRAME#	CM COORDINATES		DISPLACEMENT			VELOCITY		
	X	Y	Hor.	Ver.	LIN.	Hor.	Ver.	LIN.
1	17.77	21.86						
			0.12	-0.00	0.12	2.36	-0.06	2.36
2	20.13	21.83						
			0.13	0.01	0.13	2.47	0.20	2.48
3	22.60	22.02						
			0.13	0.02	0.13	2.38	0.40	2.42
4	24.98	22.42						
			0.15	0.04	0.15	2.78	0.71	2.87
5	27.76	23.12						
			0.08	-0.02	0.09	2.67	-0.51	2.72
6	29.36	22.82						
			0.07	-0.00	0.07	3.17	-0.03	3.17
7	30.62	22.81						
			0.15	0.00	0.15	2.93	0.07	2.93
8	33.55	22.87						
			0.09	-0.01	0.09	2.94	-0.22	2.95
9	35.31	22.74						
			0.17	-0.00	0.17	3.31	-0.01	3.31
10	38.61	22.74						
			0.15	0.00	0.15	2.78	0.05	2.78
11	41.39	22.79						
			0.18	-0.01	0.18	3.46	-0.13	3.46
12	44.84	22.65						
			0.23	-0.01	0.23	3.66	-0.17	3.66
13	49.23	22.46						
			0.18	-0.02	0.18	3.45	-0.30	3.47
14	52.68	22.16						
			0.10	0.03	0.10	2.38	0.67	2.47
15	54.58	22.69						
			0.05	0.03	0.06	2.27	1.43	2.69
16	55.49	23.26						
			0.05	0.00	0.05	2.38	0.04	2.38
17	56.44	23.28						
			0.03	0.05	0.06	1.66	2.34	2.87
18	57.10	24.22						
			0.02	0.03	0.03	0.76	1.35	1.55
19	57.40	24.76						
			0.03	0.02	0.04	1.48	1.13	1.86
20	57.99	25.21						

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CENTER OF MASS DETERMINATION FOR SUBJECT # 4 - NON PREF

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FRAME#	CM COORDINATES		DISPLACEMENT			VELOCITY		
	X	Y	Hor.	Ver.	LIN.	Hor.	Ver.	LIN.
1	56.29	29.31						
			-0.12	0.00	0.12	-2.91	0.08	2.91
2	53.91	29.37						
			-0.10	0.02	0.10	-2.29	0.49	2.35
3	52.02	29.78						
			-0.12	0.02	0.12	-2.83	0.47	2.87
4	49.70	30.16						
			-0.14	0.03	0.15	-3.41	0.62	3.47
5	46.91	30.68						
			-0.12	0.03	0.12	-2.79	0.77	2.89
6	44.62	31.30						
			-0.14	0.00	0.14	-3.30	0.04	3.30
7	41.91	31.34						
			-0.19	-0.01	0.19	-3.62	-0.25	3.63
8	38.19	31.08						
			-0.18	-0.01	0.18	-3.33	-0.17	3.33
9	34.77	30.91						
			-0.10	-0.00	0.10	-3.28	-0.10	3.28
10	32.76	30.85						
			-0.17	-0.01	0.17	-3.20	-0.12	3.20
11	29.48	30.72						
			-0.19	-0.03	0.19	-3.60	-0.62	3.66
12	25.78	30.09						
			-0.13	-0.03	0.13	-4.01	-0.85	4.10
13	23.31	29.57						
			-0.22	-0.02	0.22	-3.02	-0.29	3.04
14	18.98	29.14						
			-0.10	0.02	0.10	-2.93	0.52	2.97
15	16.98	29.50						
			-0.07	0.03	0.08	-2.28	0.83	2.43
16	15.57	30.01						
			-0.05	0.03	0.06	-2.30	1.58	2.79
17	14.63	30.66						
			-0.02	0.02	0.02	-0.82	0.85	1.18
18	14.29	31.01						
			-0.04	0.02	0.05	-1.89	1.02	2.15
19	13.52	31.43						
			-0.03	0.04	0.05	-1.54	1.74	2.32
20	12.88	32.14						

CENTER OF MASS DETERMINATION FOR SUBJECT # 4 - PREF

FRAME#	CM COORDINATES X	CM COORDINATES Y	DISPLACEMENT Hor.	DISPLACEMENT Ver.	DISPLACEMENT LIN.	VELOCITY Hor.	VELOCITY Ver.	VELOCITY LIN.
1	9.40	36.70						
			0.16	-0.02	0.16	2.49	-0.25	2.51
2	12.34	36.41						
			0.14	0.02	0.14	2.21	0.32	2.24
3	14.95	36.78						
			0.18	0.05	0.19	2.89	0.85	3.01
4	18.36	37.78						
			0.13	0.04	0.14	3.13	0.96	3.27
5	20.80	38.53						
			0.07	0.01	0.07	3.16	0.52	3.20
6	22.03	38.73						
			0.16	0.01	0.16	3.06	0.24	3.07
7	25.01	38.97						
			0.16	0.00	0.16	3.90	0.01	3.90
8	28.06	38.97						
			0.18	-0.01	0.18	3.43	-0.20	3.43
9	31.40	38.78						
			0.15	0.01	0.15	3.53	0.32	3.54
10	34.15	39.03						
			0.15	-0.00	0.15	3.52	-0.04	3.52
11	36.90	39.00						
			0.16	-0.02	0.16	3.81	-0.43	3.83
12	39.88	38.66						
			0.11	-0.05	0.13	3.63	-1.64	3.98
13	42.00	37.70						
			0.19	-0.02	0.19	3.53	-0.45	3.56
14	45.45	37.26						
			0.10	0.04	0.11	2.40	0.99	2.60
15	47.32	38.04						
			0.09	0.03	0.10	3.00	1.11	3.20
16	49.07	38.69						
			0.05	0.03	0.05	2.21	1.20	2.52
17	49.94	39.15						
			0.05	0.04	0.06	2.30	1.74	2.88
18	50.83	39.83						
			0.02	0.03	0.04	1.17	1.50	1.91
19	51.29	40.42						
			0.03	0.03	0.04	1.24	1.37	1.85
20	51.78	40.95						

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CENTER OF MASS DETERMINATION FOR SUBJECT # 5 - NON PREF

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FRAME#	CM COORDINATES X	Y	DISPLACEMENT Hor.	Ver.	LIN.	VELOCITY Hor.	Ver.	LIN.
1	89.45	26.66						
			-0.12	0.01	0.12	-2.27	0.21	2.28
2	87.40	26.85						
			-0.12	-0.01	0.12	-2.33	-0.12	2.33
3	85.30	26.74						
			-0.13	-0.01	0.13	-2.41	-0.26	2.42
4	83.13	26.51						
			-0.24	-0.02	0.24	-2.83	-0.29	2.84
5	79.05	26.09						
			-0.14	-0.02	0.14	-2.67	-0.29	2.68
6	76.65	25.83						
			-0.27	-0.00	0.27	-3.18	-0.03	3.18
7	72.06	25.80						
			-0.09	-0.00	0.09	-2.77	-0.03	2.77
8	70.57	25.78						
			-0.15	0.01	0.15	-3.59	0.30	3.60
9	67.98	25.99						
			-0.18	0.01	0.18	-3.35	0.13	3.35
10	64.96	26.12						
			-0.17	-0.01	0.17	-3.21	-0.25	3.22
11	62.07	25.89						
			-0.14	-0.02	0.14	-3.26	-0.43	3.29
12	59.72	25.58						
			-0.13	-0.02	0.13	-3.99	-0.65	4.04
13	57.56	25.23						
			-0.13	-0.02	0.13	-3.11	-0.45	3.15
14	55.31	24.91						
			-0.12	0.02	0.12	-2.87	0.54	2.92
15	53.25	25.30						
			-0.06	0.05	0.08	-1.75	1.63	2.39
16	52.30	26.17						
			-0.06	0.03	0.07	-2.05	0.95	2.26
17	51.19	26.69						
			-0.02	0.03	0.04	-1.07	1.65	1.96
18	50.81	27.28						
			-0.03	0.02	0.03	-1.48	0.72	1.64
19	50.28	27.54						
			-0.03	0.03	0.04	-1.38	1.62	2.13
20	49.78	28.13						

CENTER OF MASS DETERMINATION FOR SUBJECT # 5 - PREF

FRAME#	CM COORDINATES X	CM COORDINATES Y	DISPLACEMENT Hor.	DISPLACEMENT Ver.	DISPLACEMENT LIN.	VELOCITY Hor.	VELOCITY Ver.	VELOCITY LIN.
1	25.78	28.93						
			0.18	0.01	0.18	2.17	0.08	2.17
2	29.17	29.05						
			0.24	0.02	0.24	2.81	0.24	2.82
3	33.57	29.43						
			0.05	0.01	0.05	2.30	0.32	2.32
4	34.47	29.55						
			0.09	-0.00	0.09	2.90	-0.05	2.90
5	36.17	29.52						
			0.13	-0.00	0.13	3.01	-0.05	3.01
6	38.53	29.49						
			0.12	-0.00	0.12	2,96	-0.07	2.96
7	40.84	29.44						
			0.20	0.00	0.20	3.25	0.03	3.25
8	44.66	29.47						
			0.14	-0.00	0.14	3.45	-0.11	3.45
9	47.36	29.39						
			0.14	0.01	0.14	3.36	0.35	3.38
10	49.99	29.66						
			0.15	0.01	0.15	3.62	0.16	3.63
11	52.82	29.79						
			0.14	0.00	0.14	3.33	0.04	3.33
12	55.43	29.82						
			0.14	-0.02	0.14	3.23	-0.48	3.26
13	57.95	29.44						
			0.15	-0.02	0.16	3.68	-0.37	3.70
14	60.83	29.15						
			0.08	0.02	0.08	2.58	0.67	2.67
15	62.35	29.55						
			0.09	0.02	0.09	2.84	0.52	2.89
16	64.01	29.85						
			0.05	0.04	0.06	2.30	1.94	3.01
17	64.91	30.61						
			0.04	0.03	0.05	1.96	1.50	2.47
18	65.68	31.20						
			0.03	0.03	0.04	1.47	1.25	1.93
19	66.26	31.69						
			0.04	0.02	0.04	1.71	0.98	1.97
20	66.92	32.07						

APPENDIX D

ANGULAR RANGE OF MOTION DATA

SUBJECT 0 NONPREF

t	T>THIGH	LEG>	T	F<LL
0.000	173	116	105	107
0.063	161	125	107	103
0.126	156	133	108	103
0.189	144	146	111	96
0.252	133	150	113	88
0.315	123	151	114	84
0.420	107	138	116	80
0.525	119	131	116	85
0.588	125	132	120	70
0.662	148	133	117	66
0.714	167	147	116	74
0.767	168	161	110	89
0.872	156	111	95	127
0.924	178	82	87	134
0.977	119	112	93	118
0.998	122	165	90	123
1.008	120	176	92	129
1.029	113	168	92	136
1.050	97	171	95	124
1.071	83	172	98	121

SUBJECT 0 PREF

t	T>THIGH	LEG>	T	F<LL
0.000	153	126	74	104
0.063	144	136	74	98
0.126	136	145	74	92
0.252	113	149	70	85
0.305	117	144	72	83
0.378	123	136	72	84
0.452	129	133	69	78
0.483	133	135	68	78
0.536	149	141	69	76
0.588	178	150	73	73
0.641	163	156	76	81
0.693	150	157	82	101
0.746	153	116	91	121
0.767	155	99	95	124
0.788	167	86	98	133
0.872	137	130	106	129
0.893	125	172	100	107
0.914	119	172	100	114
0.935	112	173	101	108
0.956	90	177	95	116

SUBJECT 1 NON PREF

t	T>THIGH	LEG>	T	F<LL
0.000	118	143	115	76
0.032	117	152	113	82
0.074	117	148	112	89
0.105	122	137	111	85
0.158	120	129	112	84
0.210	129	121	108	75
0.294	142	126	111	69
0.368	178	140	105	81
0.420	158	157	101	95
0.473	147	166	99	117
0.525	139	155	96	117
0.588	136	109	83	124
0.662	180	58	76	134
0.683	171	59	71	132
0.704	150	71	69	131
0.756	122	133	66	131
0.767	127	149	64	121
0.788	122	172	65	128
0.809	120	172	63	113
0.830	125	169	60	111

SUBJECT 1 PREF

t	T>THIGH	LEG>	T	F<LL
0.000	160	99	82	80
0.105	126	112	75	81
0.210	114	142	71	80
0.315	106	147	70	77
0.336	112	144	72	81
0.357	113	139	75	81
0.483	120	123	72	75
0.546	132	126	71	71
0.672	174	133	75	71
0.725	167	141	78	87
0.777	142	156	85	110
0.830	136	142	91	117
0.882	134	107	103	119
0.924	146	81	113	131
0.956	166	69	111	130
0.998	145	98	120	127
1.029	138	150	121	129
1.050	133	177	120	123
1.071	130	170	119	117
1.092	118	172	117	120

SUBJECT 2 NONPREF

t	T>THIGH	LEG>	T	F<LL
0.000	160	106	70	96
0.063	137	105	67	90
0.126	119	113	63	89
0.189	115	121	66	82
0.252	105	130	64	71
0.336	106	132	66	70
0.389	120	126	69	73
0.441	129	122	70	63
0.473	135	118	70	50
0.515	140	118	71	57
0.578	177	125	77	64
0.641	161	143	80	84
0.704	144	144	87	116
0.746	149	111	94	125
0.809	164	77	99	134
0.861	137	117	106	105
0.903	130	178	107	129
0.935	114	174	105	123
0.956	112	171	106	123
0.977	98	178	104	121

SUBJECT 2 PREF

t	T>THIGH	LEG>	T	F<LL
0.000	168	102	102	95
0.053	156	112	105	96
0.105	133	122	111	95
0.210	122	151	113	90
0.263	121	156	113	75
0.357	116	151	110	82
0.420	119	139	110	66
0.494	124	130	112	71
0.515	126	129	110	71
0.599	143	126	109	60
0.672	177	129	101	78
0.756	152	150	98	96
0.830	135	132	86	122
0.872	149	94	78	126
0.903	173	81	74	133
0.956	130	111	77	135
0.998	121	179	81	137
1.019	109	174	82	134
1.040	101	175	84	131
1.061	89	178	87	122

SUBJECT 3 NONPREF

t	T>THIGH	LEG>	T	F<LL
0.000	166	109	113	101
0.105	124	106	120	70
0.158	119	127	118	83
0.210	111	143	121	71
0.263	119	155	121	76
0.294	125	152	119	82
0.347	128	145	119	76
0.399	144	142	116	77
0.420	143	139	117	68
0.441	158	140	113	73
0.494	177	148	111	70
0.546	154	153	99	79
0.588	145	129	87	118
0.641	177	81	79	120
0.672	137	79	81	127
0.704	122	118	80	118
0.725	123	161	74	119
0.746	112	178	79	141
0.767	110	170	77	132
0.788	95	171	79	129

SUBJECT 3 PREF

t	T>THIGH	LEG>	T	F<LL
0.000	177	108	72	109
0.053	170	94	75	97
0.105	152	112	73	66
0.158	134	131	71	98
0.210	137	147	73	73
0.242	137	148	75	78
0.263	140	144	76	79
0.315	150	131	77	81
0.347	161	130	80	83
0.399	180	136	80	71
0.452	162	150	80	64
0.504	136	159	87	82
0.567	135	121	95	125
0.620	158	84	104	143
0.662	140	91	104	135
0.683	132	126	103	125
0.704	121	174	104	140
0.725	123	178	104	120
0.746	107	170	98	117
0.767	93	173	96	115

SUBJECT 4 NONPREF

t	T>THIGH	LEG>	T	F<LL
0.000	130	95	116	94
0.042	117	91	116	86
0.084	101	93	118	84
0.126	100	107	117	82
0.168	108	117	111	82
0.210	111	126	112	91
0.252	131	129	107	85
0.305	161	137	102	71
0.357	177	142	100	82
0.389	175	147	102	74
0.441	152	157	95	87
0.494	137	148	86	120
0.525	139	121	80	119
0.599	155	74	74	113
0.634	136	87	70	102
0.665	123	127	68	104
0.686	131	161	63	95
0.707	120	177	68	93
0.728	117	167	67	91
0.749	112	167	65	99

SUDJECT 4 PREF

t	T>THICH	LEC>	T	F<LL
0.000	170	108	73	110
0.064	142	92	71	94
0.127	111	100	66	88
0.191	110	122	67	95
0.233	120	131	68	101
0.254	125	136	69	98
0.306	142	141	70	86
0.348	165	144	75	94
0.401	169	153	79	85
0.443	152	165	83	96
0.485	140	174	85	107
0.527	131	148	94	119
0.558	134	117	99	125
0.611	158	79	106	137
0.653	147	80	106	130
0.684	139	117	112	126
0.705	142	153	113	114
0.726	140	176	112	119
0.747	132	163	111	114
0.768	116	172	108	108

SUBJECT 5 NONPREF

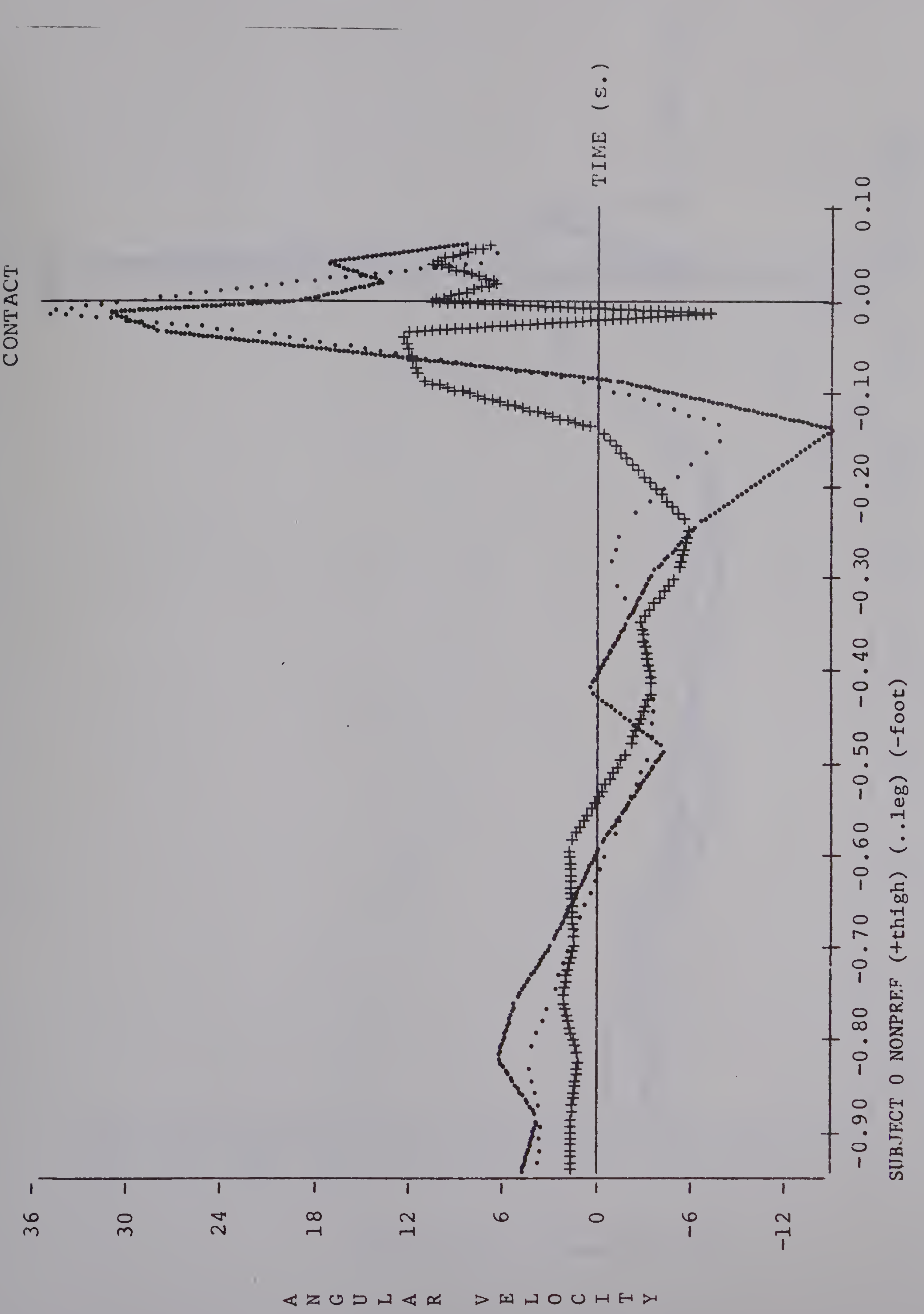
t	T>THICH	LEC>	T	F<LL
0.000	128	108	129	95
0.053	113	118	134	85
0.105	107	130	134	77
0.158	103	147	133	75
0.242	106	149	129	78
0.294	113	141	126	74
0.378	130	133	123	67
0.410	137	129	121	63
0.452	153	130	117	66
0.504	170	139	113	81
0.557	169	140	103	92
0.599	170	128	96	121
0.630	156	103	82	128
0.672	178	68	75	130
0.714	136	80	74	129
0.746	124	112	71	120
0.777	121	162	72	120
0.798	118	179	73	117
0.819	104	171	76	119
0.840	96	173	77	117

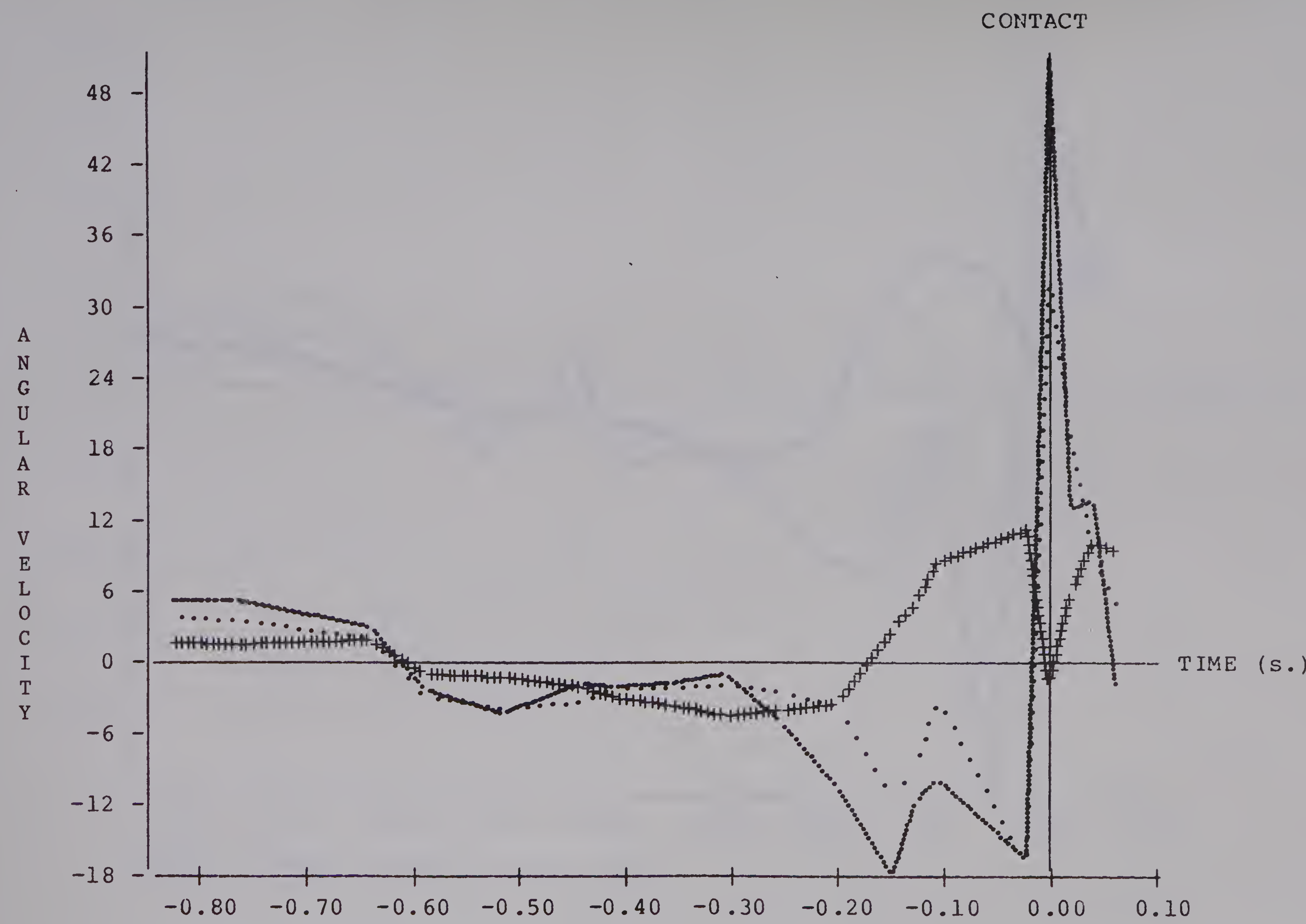
SUBJECT 5 PREF

t	T>THIGH	LEG>	T	F<LL
0.000	134	96	61	97
0.084	104	111	55	91
0.168	120	140	63	88
0.189	116	144	62	78
0.221	124	145	64	92
0.263	133	141	66	71
0.305	137	141	65	69
0.368	156	135	68	72
0.410	176	140	73	70
0.452	171	150	75	77
0.494	157	152	80	105
0.536	151	136	88	109
0.578	159	100	95	115
0.620	174	81	104	122
0.651	159	94	103	123
0.683	122	110	104	124
0.704	130	146	106	131
0.725	126	173	105	134
0.746	121	176	106	123
0.767	107	175	101	124

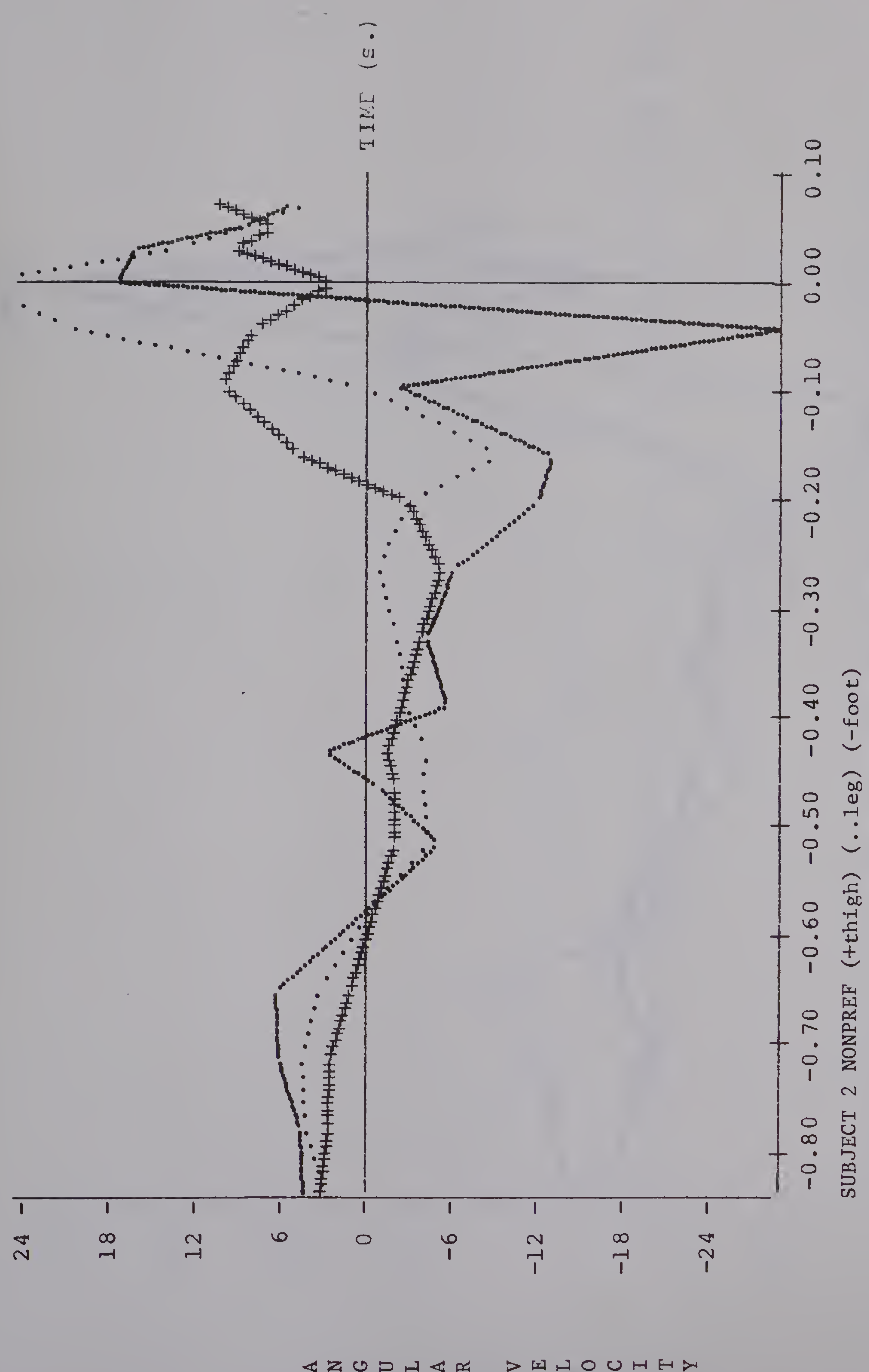
APPENDIX E

ELECTROMYOGRAPHY AND ANGULAR VELOCITY DATA


CONTACT
TIME (s.)
A N G U L A R V E L O C I T Y
36
30
24
18
12
6
0
-6
-12
-0.90 -0.80 -0.70 -0.60 -0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10
SUBJECT O NONPREF (+thigh) (..leg) (-foot)



SUBJECT 0 PREF (+thigh) (..leg) (-foot)


TIME (s.)
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0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
-0.70
-0.80
SUBJECT 2 NONPREF (+thigh) (..leg) (-foot)
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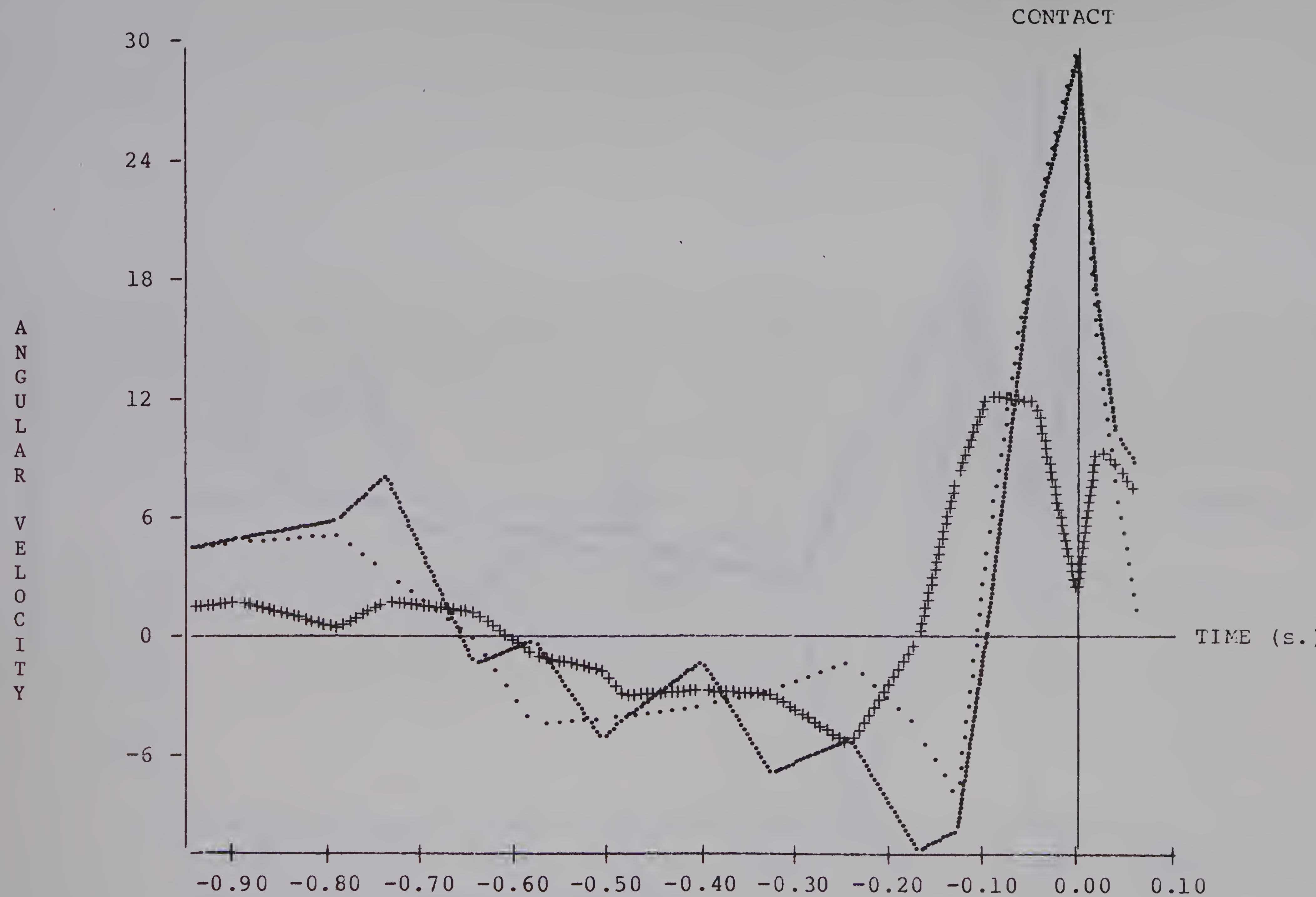
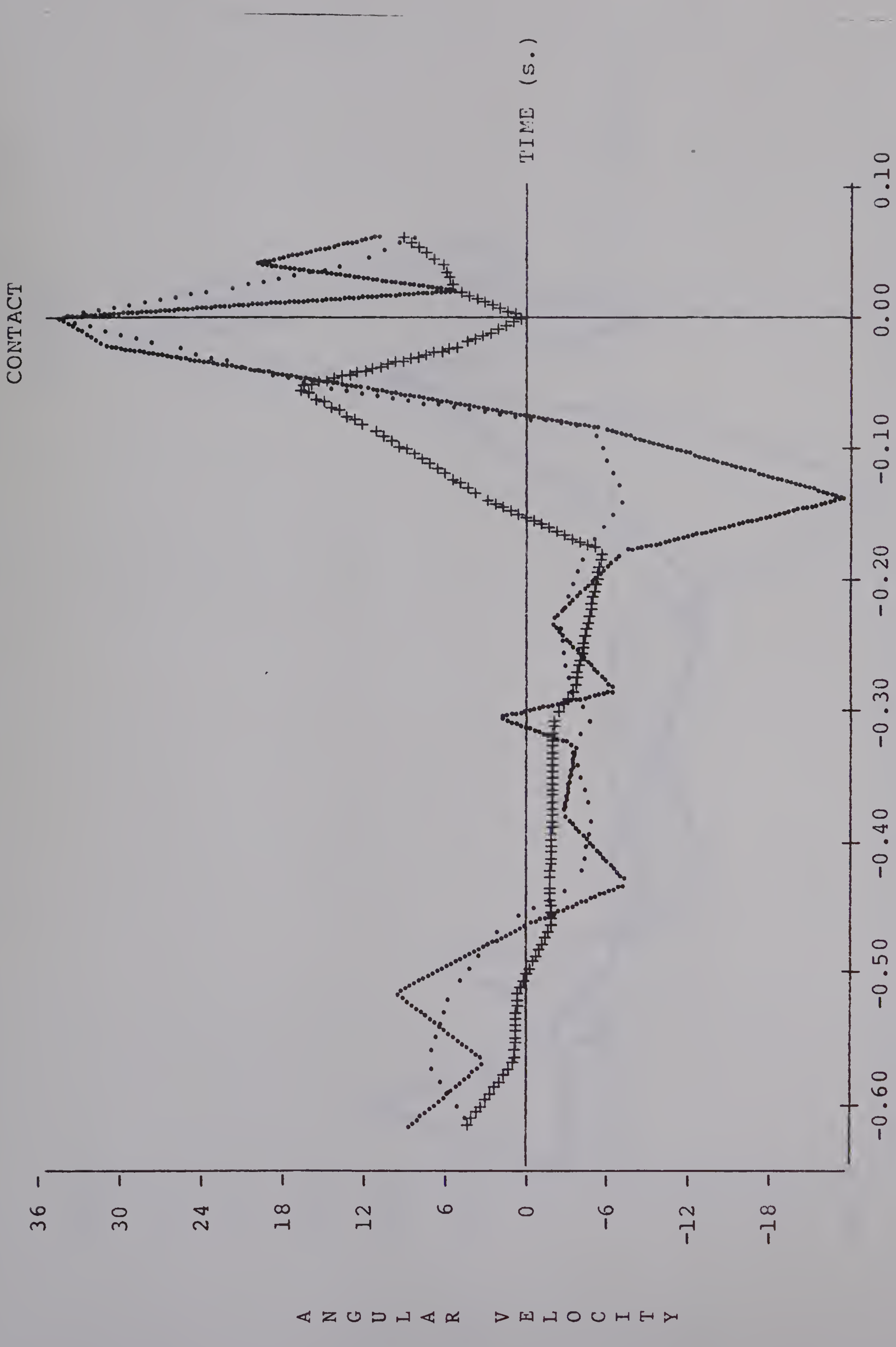
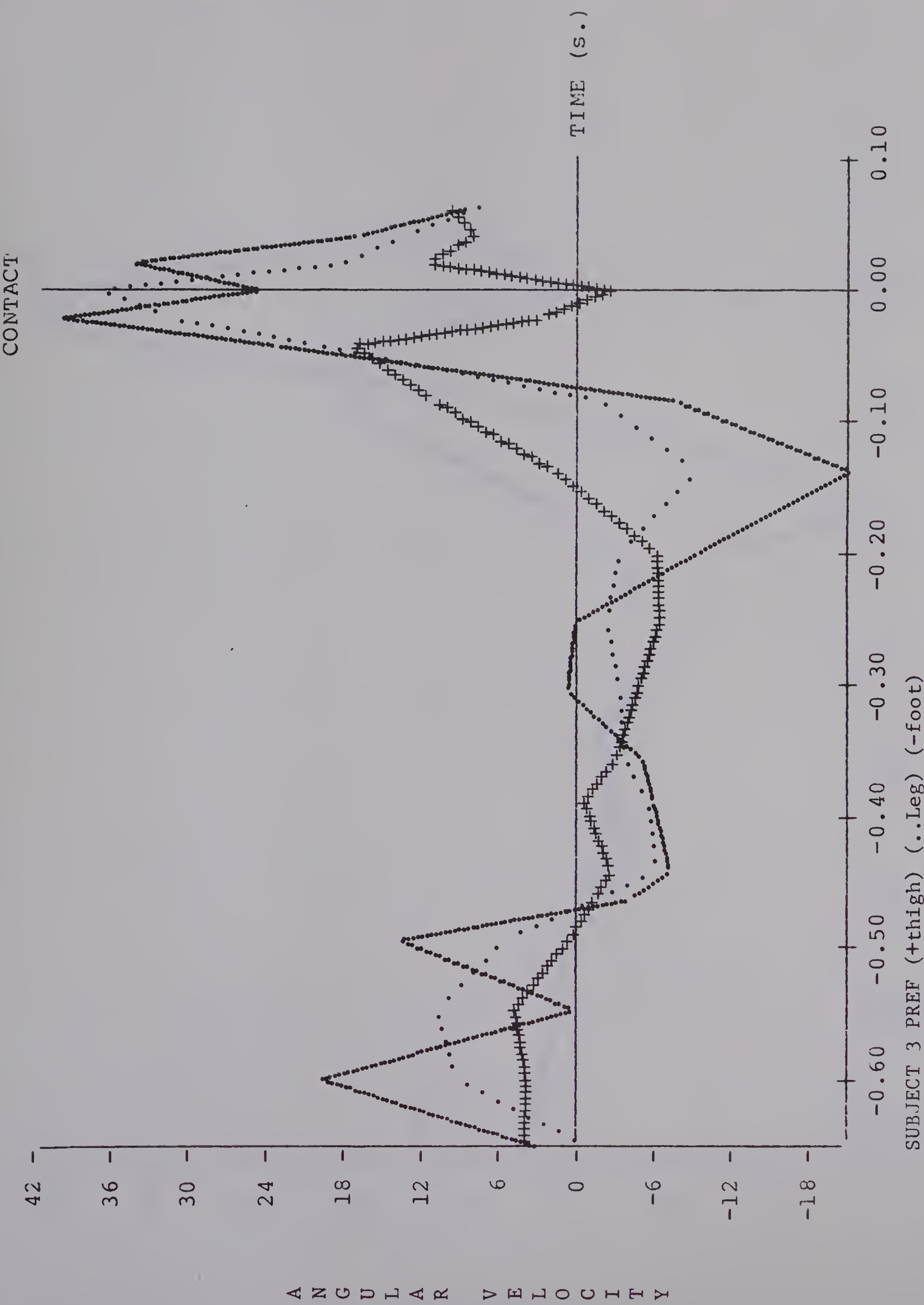
18
12
6
0
-6
-12
-18
-24
ANGULAR VELOCITY



SUBJECT 2 PREF (+thigh) (..leg) (-foot)



SUBJECT 3 NONPREF (+thigh) (..leg) (-foot)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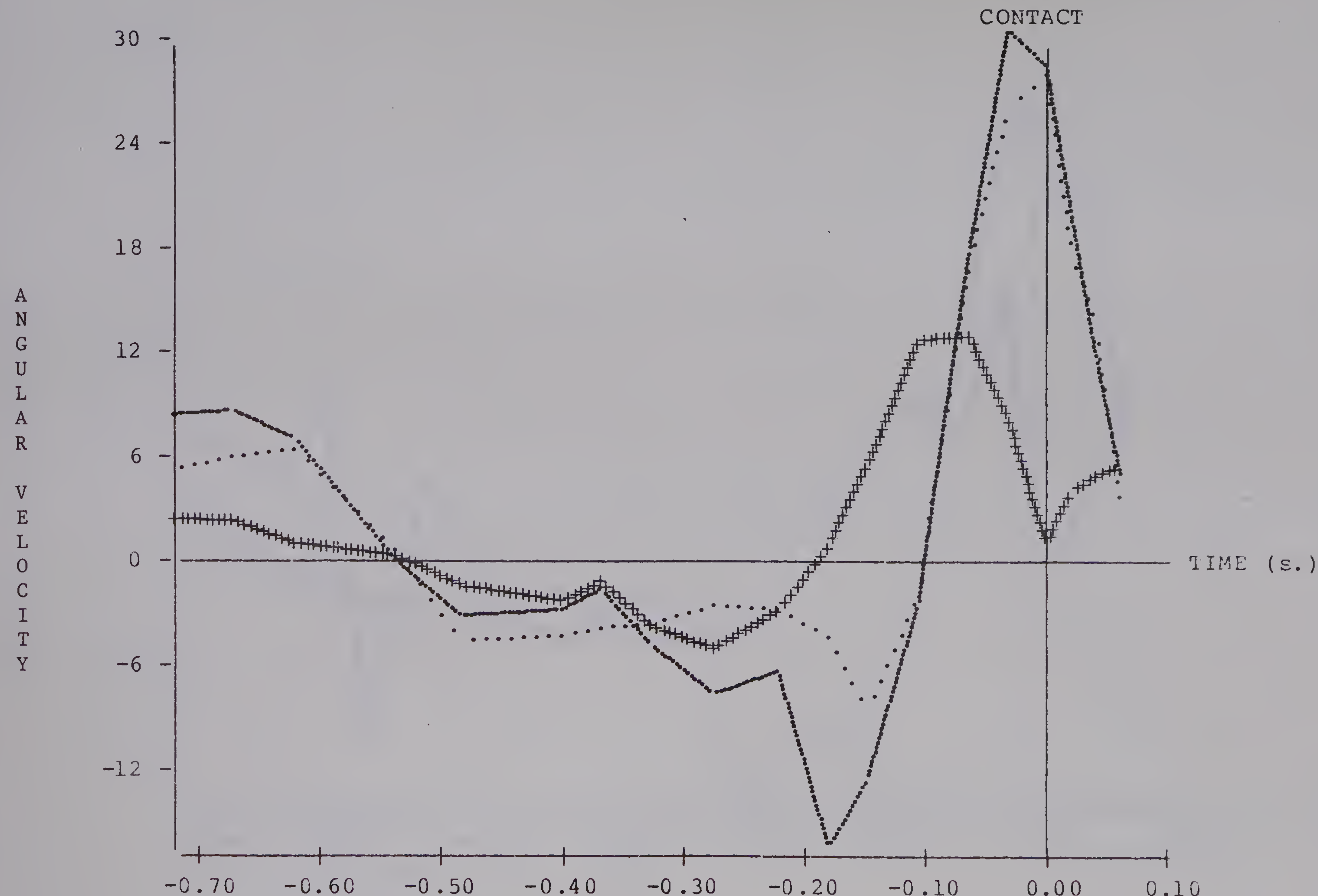
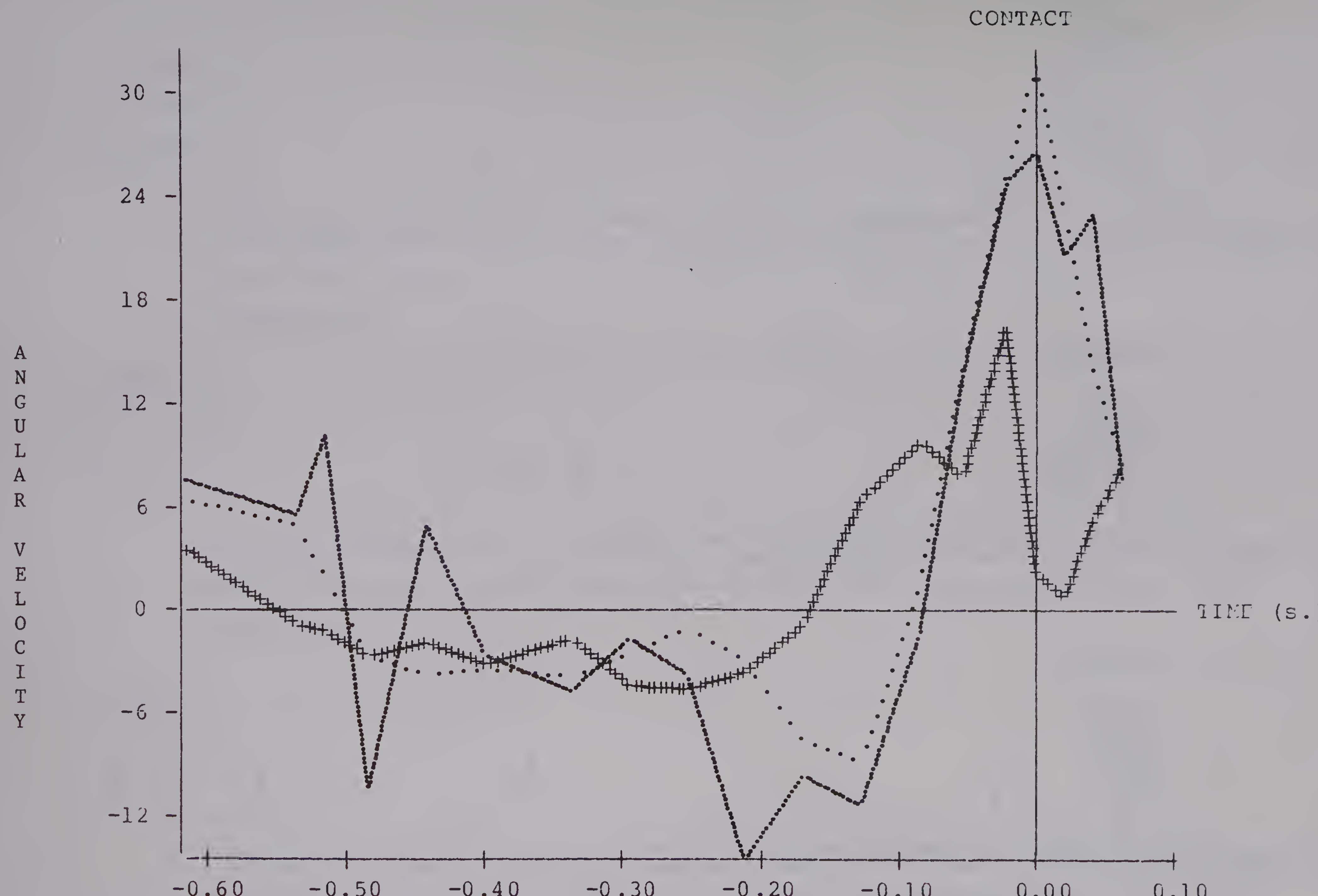
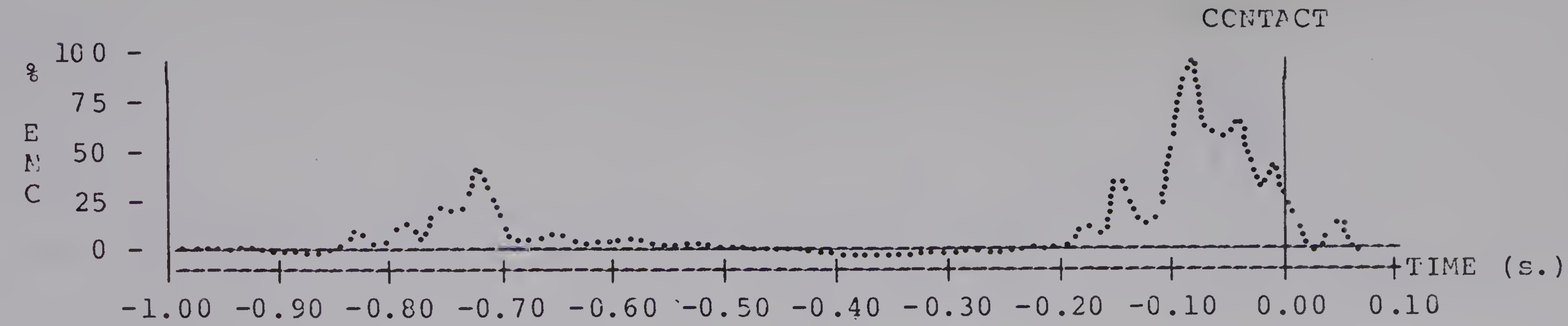
-0.20
-0.30
-0.40
-0.50
-0.60
42
36
30
24
18
12
6
0
-6
-12
-18
ANGULAR VELOCITY
SUBJECT 3 PREF (+thigh) (..Leg) (-foot)



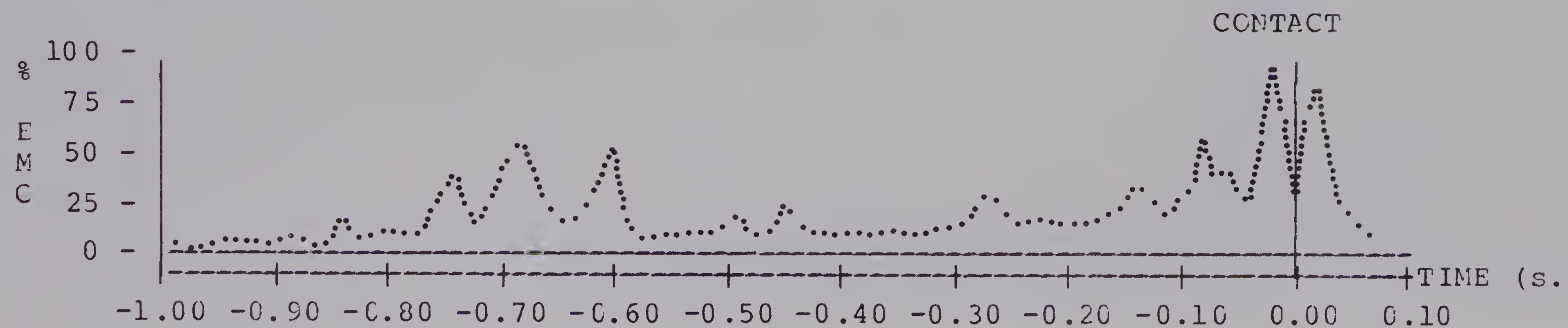
SUBJECT 5 NONPREF (+thigh) (..leg) (-foot)



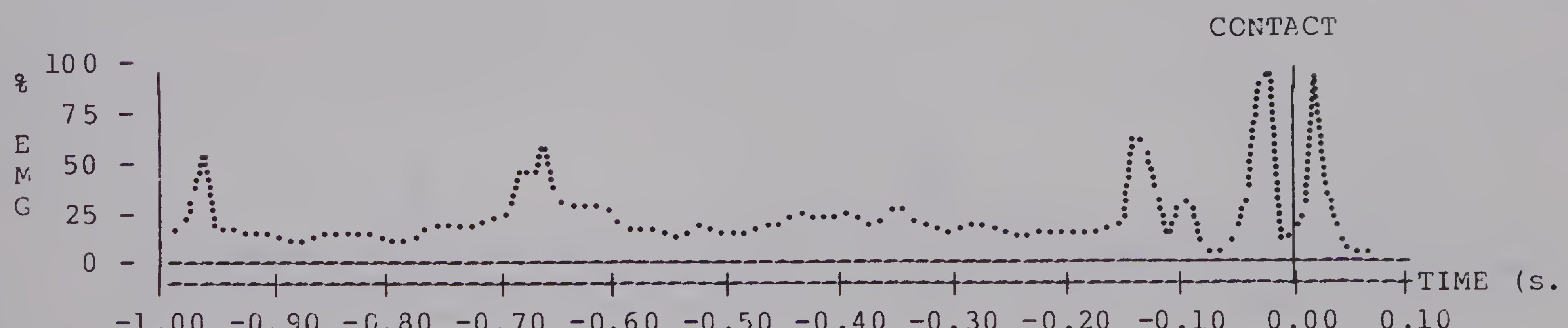
SUBJECT 5 PREF (+thigh) (..leg) (-foot)



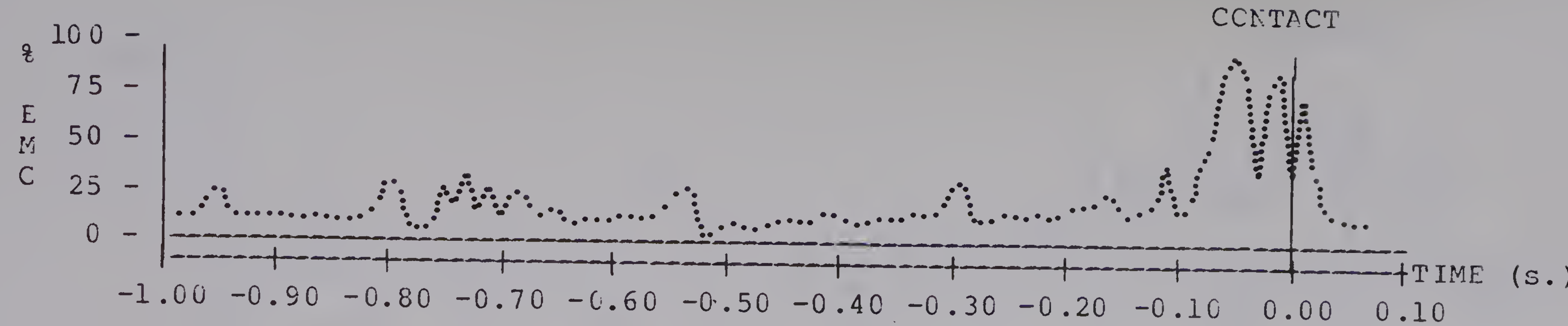
QUADS-0-NP



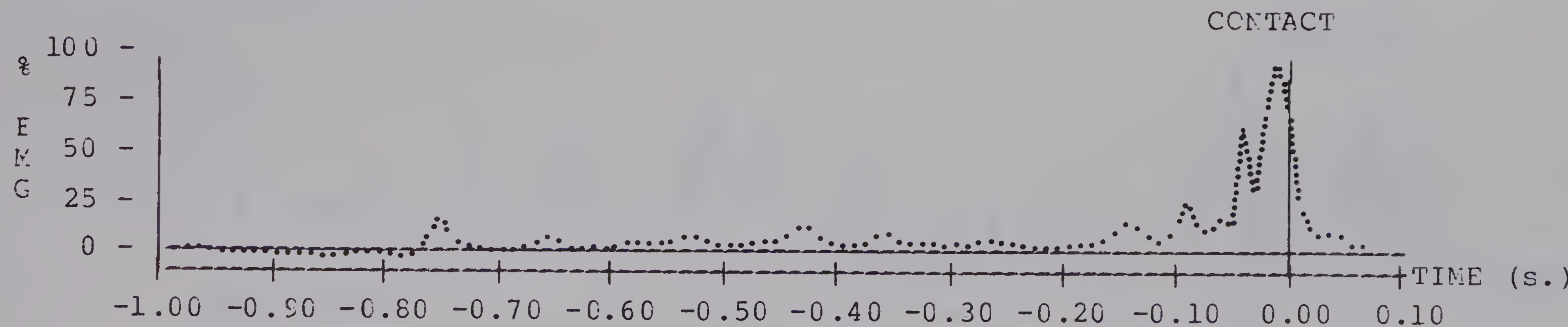
HAMS-0-NP



TIB ANT-0-NP



HAMS-0-P



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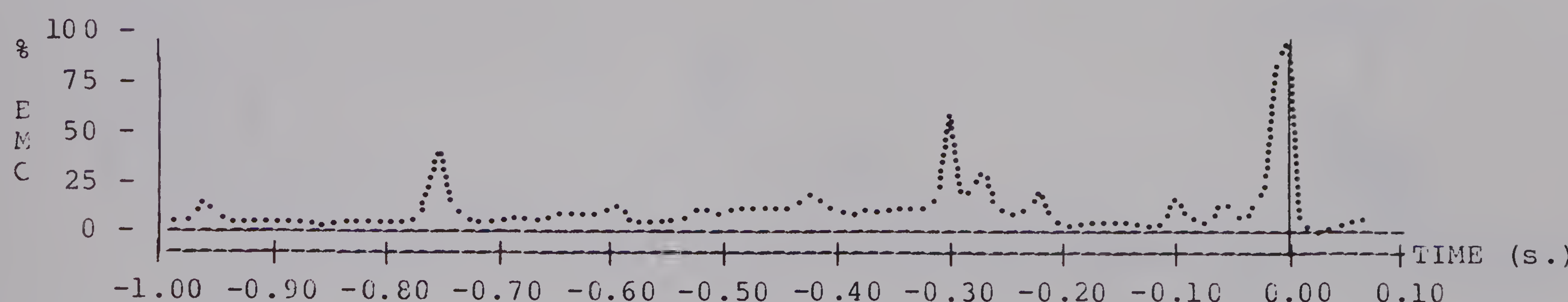

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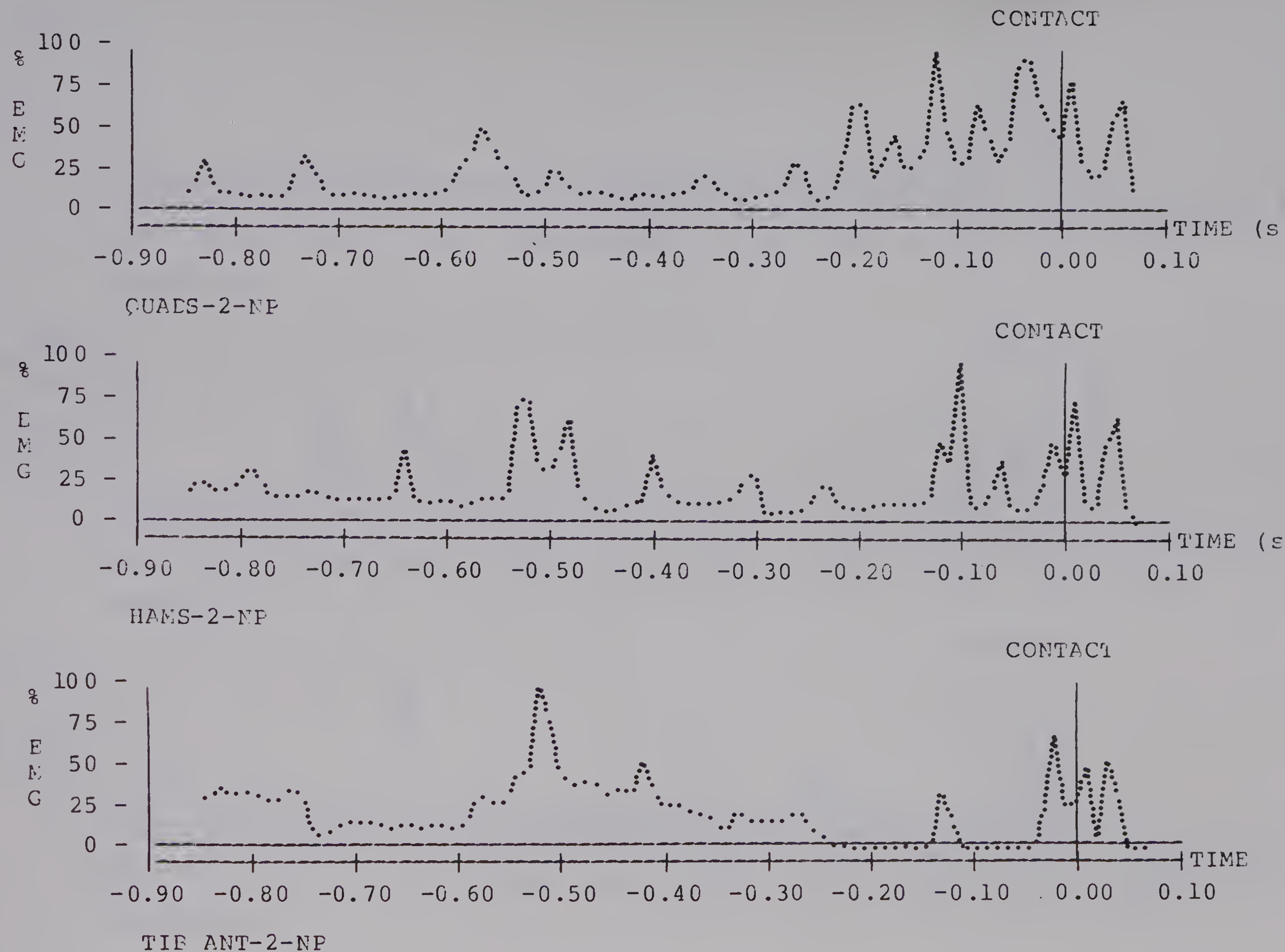
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75
50
25
0
TIME (s
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QUADS-2-NP
CONTACT
% EMG
100
75
50
25
0
TIME (s
-0.90 -0.80 -0.70 -0.60 -0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10
HAMS-2-NP
CONTACT
% EMG
100
75
50
25
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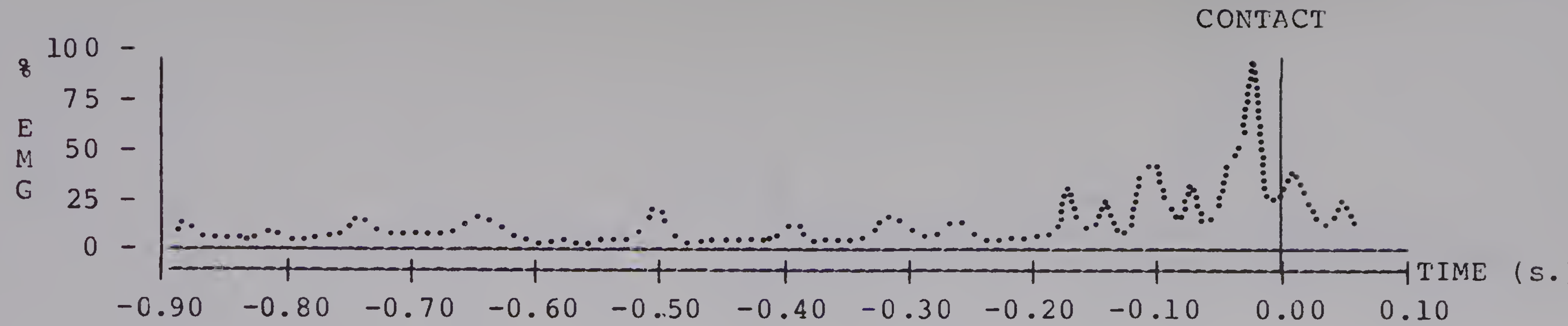
TIME
-0.90 -0.80 -0.70 -0.60 -0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10
TIB ANT-2-NP



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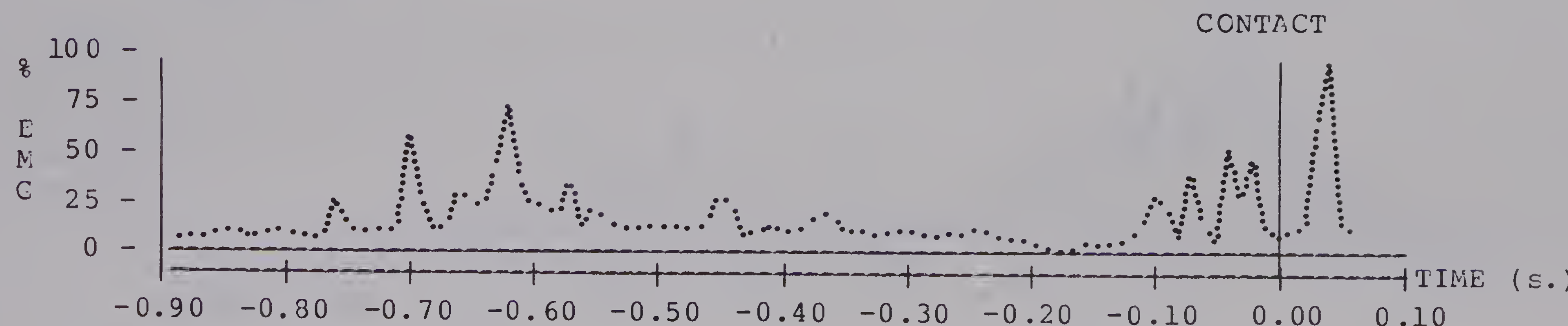

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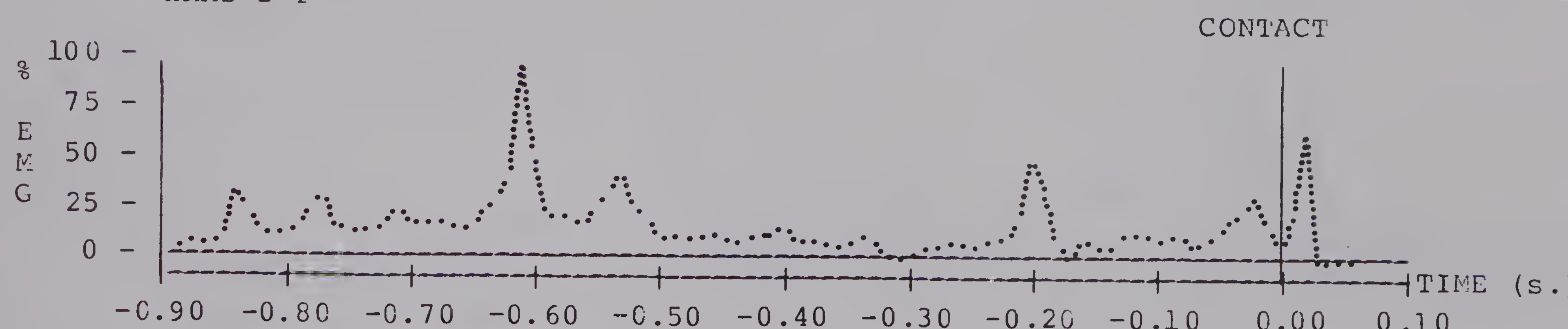

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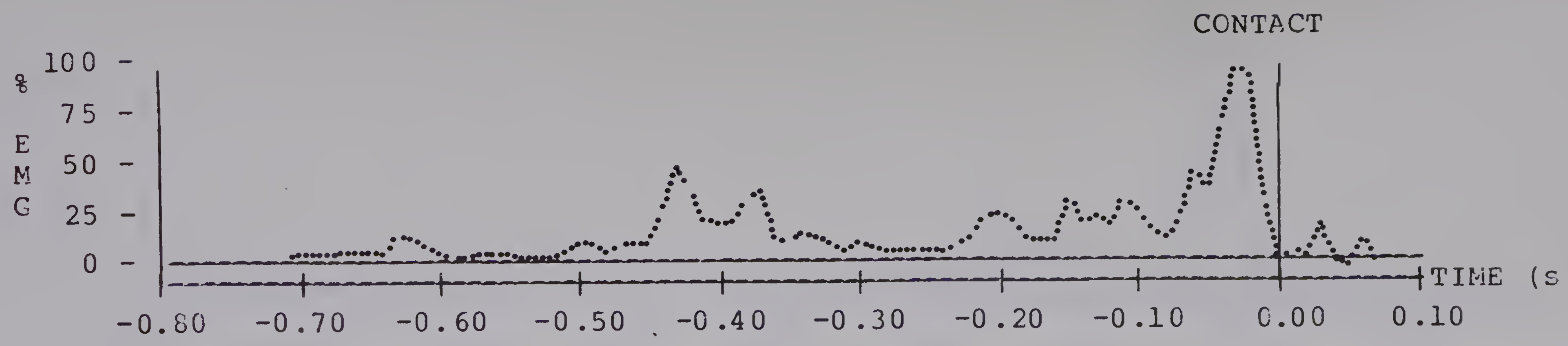

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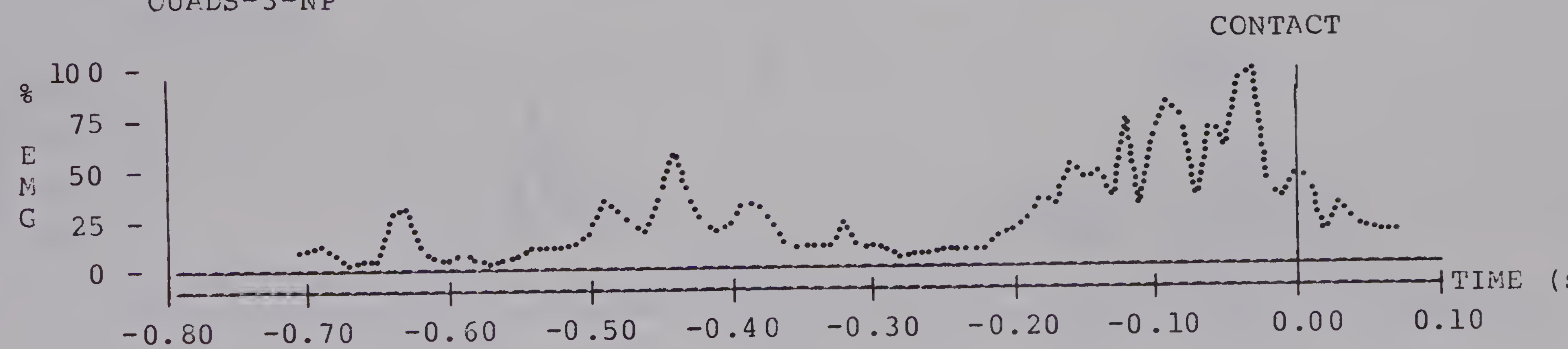

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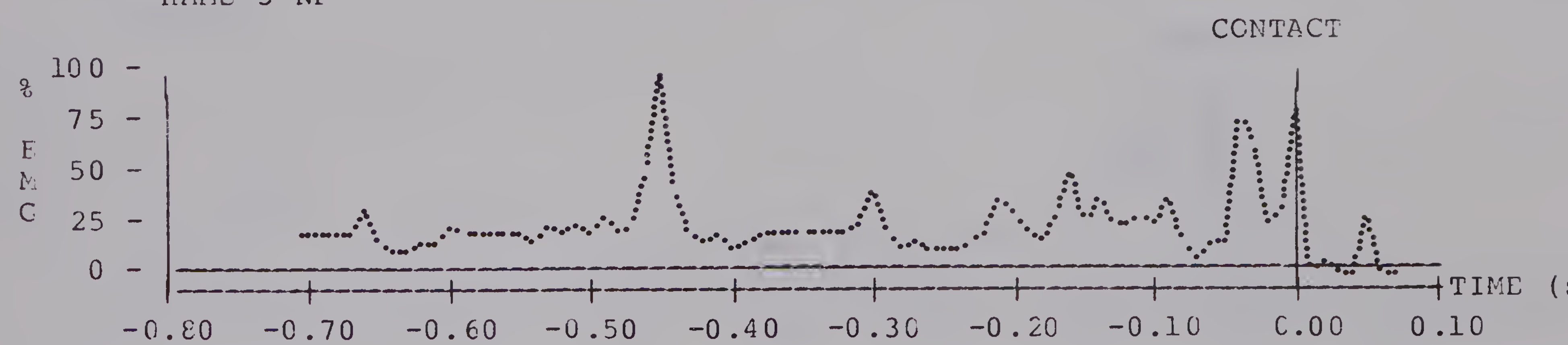

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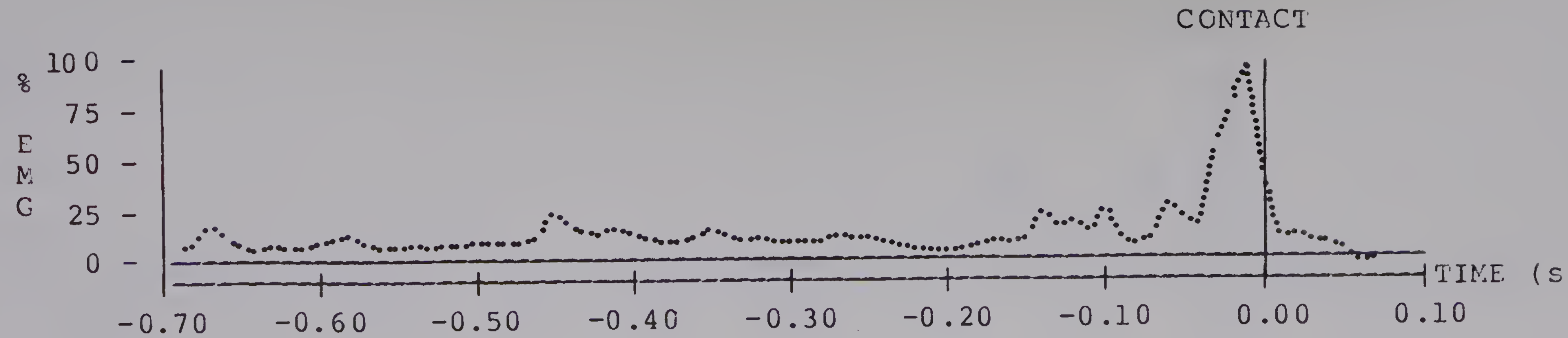

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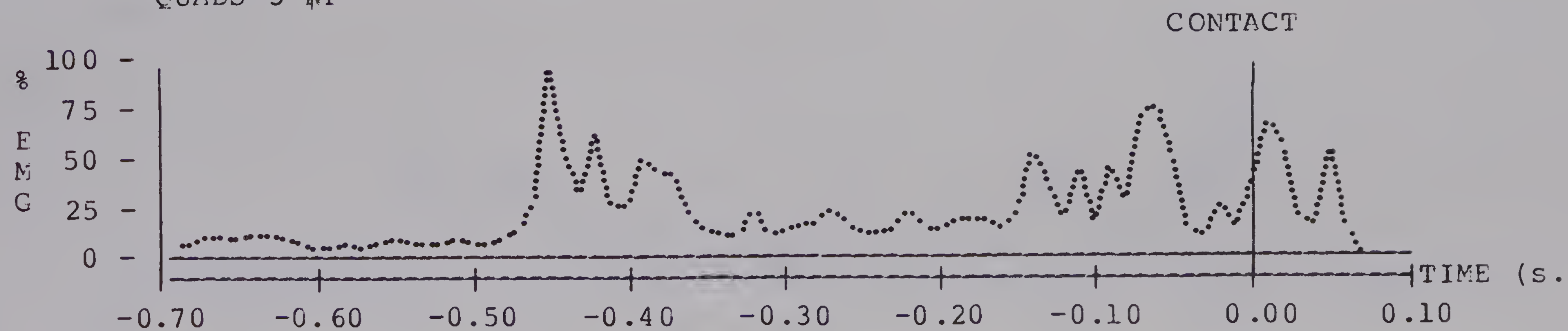
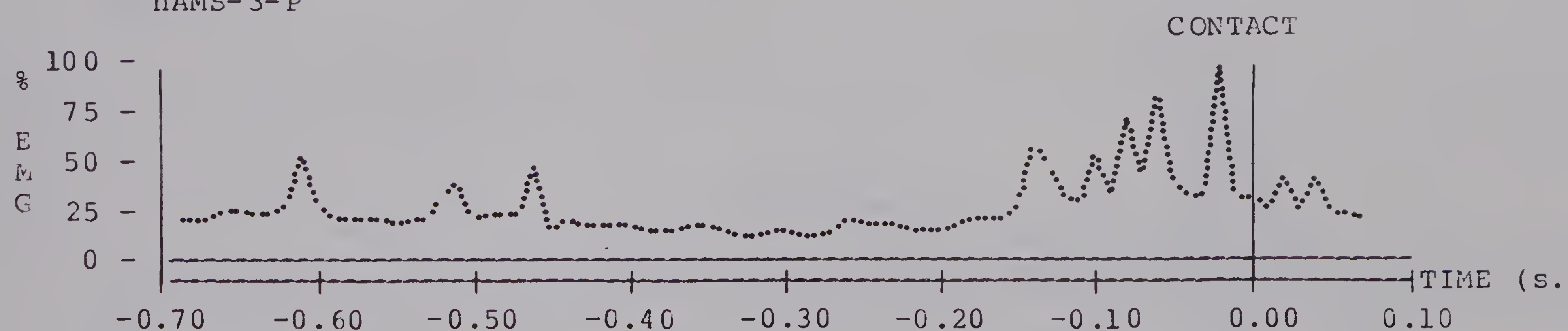


HAMS-3-P



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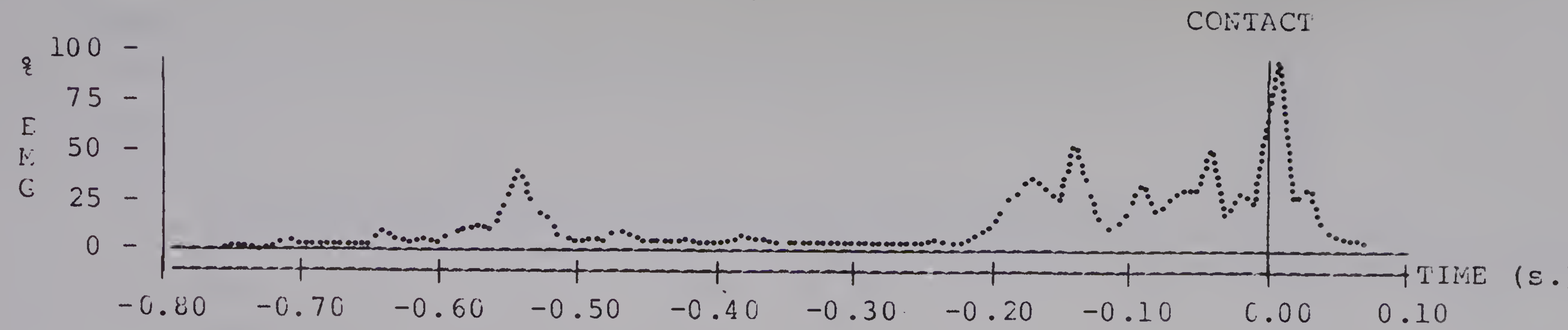

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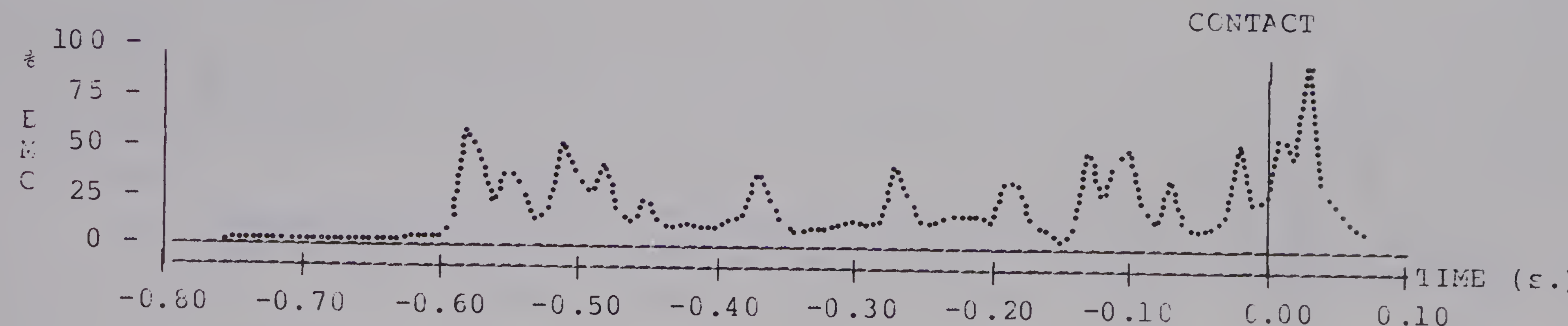

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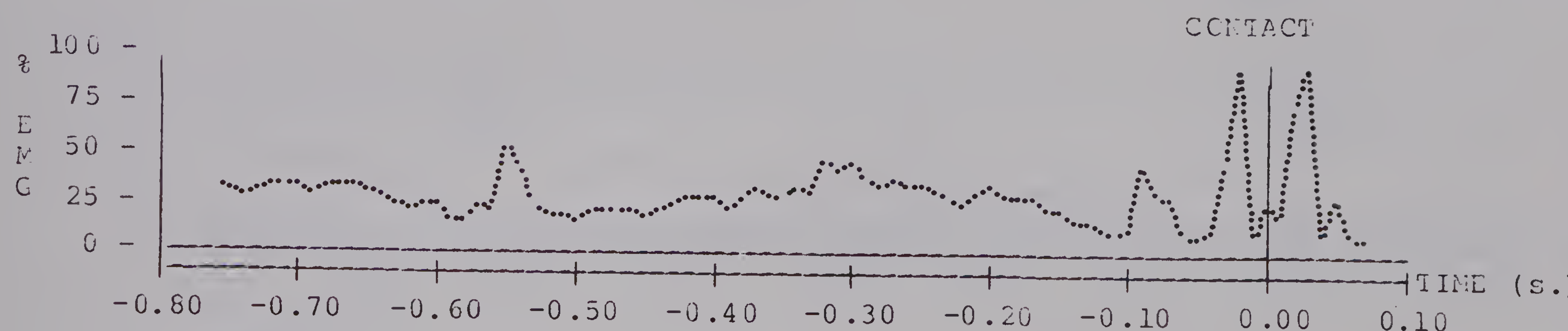

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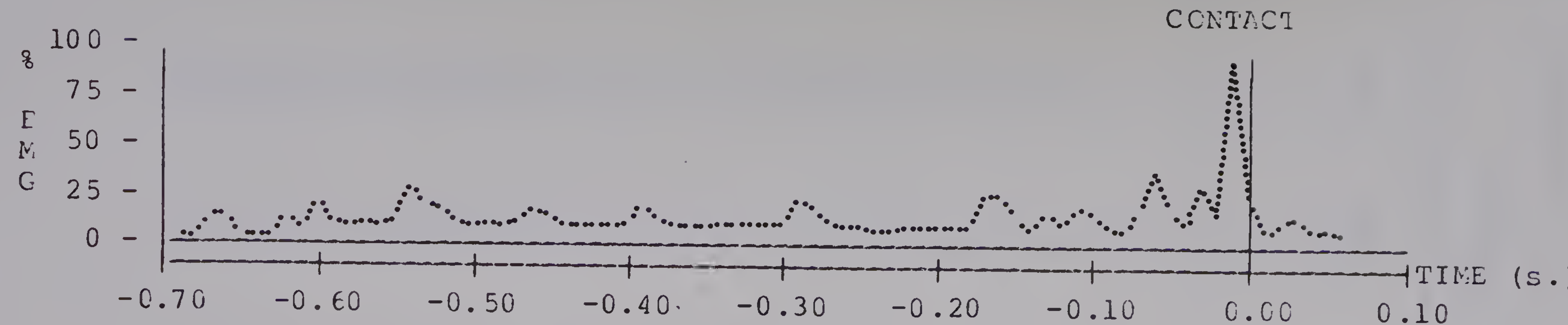

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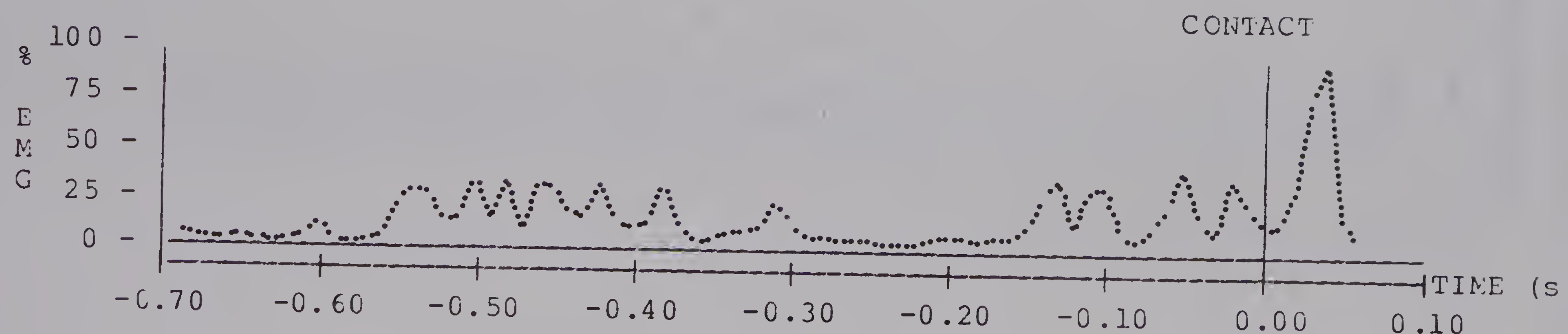

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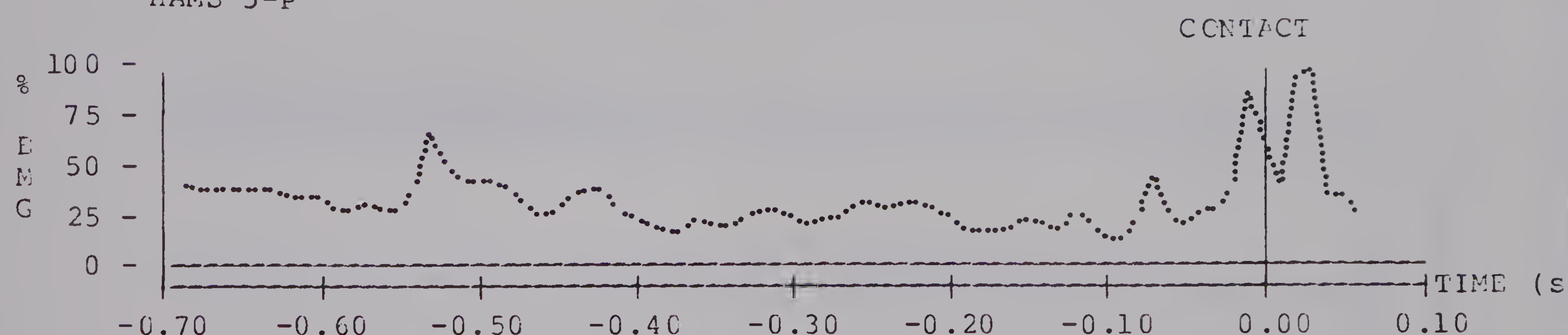

TIB ANT-5-P

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SUBJECT 0 NONPREF-QUADS

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5	4	43	8	81	5
6	3	44	6	82	18
7	4	45	4	83	13
8	4	46	5	84	11
9	3	47	6	85	43
10	2	48	6	86	31
11	3	49	5	87	19
12	2	50	4	88	16
13	2	51	4	89	23
14	2	52	4	90	60
15	5	53	3	91	94
16	5	54	3	92	100
17	14	55	3	93	66
18	9	56	3	94	64
19	4	57	3	95	61
20	11	58	2	96	74
21	19	59	2	97	49
22	18	60	2	98	35
23	9	61	1	99	49
24	25	62	1	100	30
25	27	63	1	101	19
26	21	64	1	102	4
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32	9	70	2	108	0
33	9	71	2	109	0
34	11	72	3	110	0
35	12	73	2	111	0
36	9	74	2	112	0
37	6	75	2	113	0
38	6	76	3	114	0

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SUBJECT 0 NONPREF-HAMS

****

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4	9	42	12	80	20
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6	12	44	14	82	20
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9	9	47	15	85	29
10	9	48	14	86	42
11	12	49	15	87	34
12	12	50	20	88	26
13	9	51	25	89	23
14	7	52	14	90	34
15	9	53	14	91	39
16	25	54	17	92	65
17	12	55	29	93	42
18	10	56	21	94	50
19	14	57	14	95	36
20	15	58	15	96	29
21	14	59	14	97	64
22	14	60	14	98	100
23	14	61	15	99	76
24	26	62	14	100	32
25	36	63	14	101	76
26	45	64	15	102	92
27	28	65	15	103	59
28	18	66	14	104	28
29	29	67	14	105	23
30	43	68	15	106	17
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32	62	70	18	108	0
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34	29	72	31	110	0
35	23	73	36	111	0
36	18	74	28	112	0
37	25	75	21	113	0
38	32	76	18	114	0

****

SUBJECT 0 NONPREF-TIB ANT

****

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24	22	62	22	100	18
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26	22	64	26	102	99
27	22	65	34	103	42
28	22	66	26	104	18
29	26	67	22	105	6
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32	55	70	18	108	0
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37	34	75	18	113	0
38	30	76	14	114	0

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SUBJECT 0 PREF-QUADS

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6	1	44	7	82	7
7	2	45	8	83	8
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15	1	53	7	91	31
16	1	54	9	92	18
17	1	55	9	93	12
18	2	56	14	94	21
19	2	57	18	95	15
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21	1	59	9	97	33
22	1	60	7	98	75
23	2	61	6	99	100
24	11	62	6	100	77
25	21	63	7	101	28
26	10	64	15	102	15
27	6	65	10	103	10
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29	3	67	8	105	9
30	3	68	8	106	7
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32	4	70	6	108	0
33	6	71	7	109	0
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35	12	73	10	111	0
36	5	74	10	112	0
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****

SUBJECT 0 PREF-BANS

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5	32	43	15	81	25
6	15	44	18	82	22
7	15	45	25	83	27
8	15	46	32	84	32
9	15	47	32	85	20
10	15	48	6	86	18
11	15	49	8	87	22
12	13	50	13	88	25
13	15	51	13	89	45
14	15	52	11	90	18
15	13	53	11	91	25
16	13	54	13	92	45
17	13	55	15	93	57
18	15	56	15	94	94
19	20	57	13	95	100
20	36	58	15	96	89
21	32	59	20	97	38
22	8	60	18	98	85
23	11	61	13	99	94
24	11	62	13	100	38
25	32	63	15	101	82
26	20	64	18	102	43
27	41	65	15	103	22
28	18	66	18	104	18
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32	29	70	34	108	0
33	18	71	36	109	0
34	15	72	15	110	0
35	22	73	15	111	0
36	11	74	18	112	0
37	13	75	20	113	0
38	15	76	18	114	0

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SUBJECT 0 PREF-TIB ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
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5	13	43	9	81	7
6	9	44	9	82	9
7	9	45	9	83	9
8	9	46	11	84	9
9	9	47	11	85	9
10	9	48	17	86	9
11	9	49	13	87	7
12	9	50	13	88	7
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16	9	54	15	92	9
17	9	55	15	93	9
18	9	56	15	94	19
19	9	57	21	95	15
20	9	58	23	96	9
21	9	59	15	97	19
22	9	60	15	98	29
23	11	61	13	99	93
24	27	62	13	100	100
25	48	63	15	101	11
26	17	64	13	102	3
27	11	65	15	103	5
28	9	66	15	104	7
29	9	67	15	105	9
30	9	68	15	106	11
31	11	69	23	107	11
32	11	70	64	108	0
33	11	71	21	109	0
34	9	72	25	110	0
35	13	73	36	111	0
36	13	74	17	112	0
37	13	75	13	113	0
38	13	76	13	114	0

****

SUBJECT 1 NONPREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	14	39	14	77	28
2	14	40	14	78	21
3	21	41	15	79	15
4	29	42	17	80	15
5	41	43	17	81	0
6	51	44	14	82	0
7	54	45	15	83	0
8	42	46	17	84	0
9	33	47	21	85	0
10	27	48	26	86	0
11	28	49	26	87	0
12	32	50	19	88	0
13	41	51	15	89	0
14	27	52	21	90	0
15	23	53	27	91	0
16	22	54	47	92	0
17	14	55	52	93	0
18	17	56	35	94	0
19	18	57	32	95	0
20	13	58	37	96	0
21	17	59	27	97	0
22	18	60	43	98	0
23	15	61	59	99	0
24	21	62	59	100	0
25	18	63	23	101	0
26	13	64	59	102	0
27	13	65	43	103	0
28	13	66	38	104	0
29	12	67	70	105	0
30	12	68	64	106	0
31	12	69	59	107	0
32	13	70	100	108	0
33	13	71	90	109	0
34	14	72	90	110	0
35	14	73	80	111	0
36	15	74	61	112	0
37	14	75	33	113	0
38	14	76	57	114	0

****

SUBJECT 1 NONPREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	14	39	21	77	49
2	21	40	23	78	19
3	32	41	25	79	14
4	30	42	23	80	12
5	53	43	23	81	0
6	100	44	25	82	0
7	56	45	23	83	0
8	30	46	23	84	0
9	19	47	23	85	0
10	40	48	25	86	0
11	40	49	32	87	0
12	77	50	45	88	0
13	43	51	43	89	0
14	23	52	23	90	0
15	36	53	14	91	0
16	23	54	14	92	0
17	27	55	14	93	0
18	27	56	17	94	0
19	40	57	19	95	0
20	25	58	56	96	0
21	32	59	100	97	0
22	17	60	66	98	0
23	17	61	19	99	0
24	14	62	34	100	0
25	14	63	49	101	0
26	14	64	62	102	0
27	17	65	84	103	0
28	19	66	58	104	0
29	19	67	23	105	0
30	21	68	23	106	0
31	21	69	12	107	0
32	21	70	17	108	0
33	21	71	17	109	0
34	19	72	27	110	0
35	23	73	36	111	0
36	34	74	4	112	0
37	25	75	4	113	0
38	23	76	45	114	0

****

SUBJECT 1 NONPREF-TIB ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	10	39	10	77	4
2	10	40	6	78	10
3	10	41	4	79	13
4	15	42	6	80	8
5	13	43	8	81	0
6	24	44	8	82	0
7	52	45	10	83	0
8	26	46	13	84	0
9	13	47	10	85	0
10	13	48	10	86	0
11	13	49	13	87	0
12	13	50	15	88	0
13	13	51	41	89	0
14	15	52	10	90	0
15	10	53	8	91	0
16	8	54	8	92	0
17	13	55	8	93	0
18	13	56	6	94	0
19	15	57	8	95	0
20	17	58	8	96	0
21	21	59	6	97	0
22	15	60	10	98	0
23	13	61	30	99	0
24	15	62	17	100	0
25	15	63	10	101	0
26	15	64	15	102	0
27	13	65	13	103	0
28	10	66	43	104	0
29	13	67	43	105	0
30	13	68	13	106	0
31	13	69	13	107	0
32	10	70	21	108	0
33	10	71	50	109	0
34	10	72	100	110	0
35	8	73	13	111	0
36	6	74	19	112	0
37	6	75	8	113	0
38	6	76	8	114	0

****

SUBJECT 1 PREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	10	39	13	77	21
2	9	40	12	78	31
3	9	41	10	79	40
4	9	42	12	80	23
5	10	43	12	81	37
6	12	44	12	82	52
7	12	45	10	83	22
8	12	46	13	84	70
9	9	47	23	85	81
10	7	48	10	86	56
11	7	49	7	87	40
12	3	50	7	88	40
13	0	51	8	89	57
14	7	52	8	90	73
15	7	53	21	91	100
16	5	54	16	92	78
17	5	55	12	93	22
18	4	56	12	94	37
19	4	57	12	95	18
20	3	58	13	96	9
21	3	59	16	97	9
22	4	60	16	98	27
23	5	61	13	99	16
24	8	62	12	100	12
25	5	63	13	101	12
26	8	64	14	102	10
27	12	65	18	103	9
28	30	66	18	104	9
29	25	67	23	105	8
30	34	68	21	106	9
31	43	69	12	107	0
32	20	70	9	108	0
33	20	71	10	109	0
34	16	72	14	110	0
35	16	73	14	111	0
36	23	74	16	112	0
37	20	75	14	113	0
38	16	76	16	114	0

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SUBJECT 1 PREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	10	39	44	77	20
2	13	40	29	78	22
3	17	41	43	79	27
4	29	42	25	80	29
5	20	43	20	81	32
6	20	44	15	82	60
7	20	45	15	83	46
8	20	46	17	84	25
9	39	47	20	85	25
10	32	48	22	86	27
11	15	49	22	87	29
12	15	50	27	88	53
13	34	51	17	89	41
14	20	52	13	90	53
15	13	53	15	91	100
16	10	54	13	92	94
17	10	55	15	93	53
18	15	56	17	94	25
19	29	57	15	95	27
20	44	58	15	96	41
21	36	59	15	97	41
22	15	60	17	98	39
23	13	61	25	99	56
24	15	62	27	100	44
25	27	63	20	101	41
26	25	64	13	102	96
27	20	65	10	103	56
28	17	66	13	104	32
29	46	67	15	105	22
30	58	68	20	106	22
31	27	69	17	107	0
32	27	70	17	108	0
33	84	71	20	109	0
34	96	72	22	110	0
35	34	73	29	111	0
36	48	74	39	112	0
37	36	75	29	113	0
38	67	76	22	114	0

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SUBJECT 1 PREF-TIB ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	47	39	18	77	18
2	39	40	18	78	18
3	32	41	18	79	22
4	22	42	22	80	25
5	18	43	18	81	25
6	29	44	18	82	29
7	57	45	18	83	39
8	22	46	18	84	22
9	15	47	18	85	29
10	15	48	15	86	29
11	11	49	15	87	25
12	11	50	25	88	25
13	8	51	15	89	25
14	4	52	11	90	22
15	11	53	15	91	15
16	50	54	15	92	22
17	32	55	15	93	15
18	11	56	11	94	18
19	15	57	11	95	22
20	15	58	15	96	43
21	8	59	18	97	18
22	11	60	18	98	36
23	43	61	18	99	71
24	15	62	36	100	54
25	25	63	22	101	25
26	22	64	15	102	11
27	22	65	18	103	11
28	61	66	18	104	11
29	47	67	22	105	8
30	100	68	18	106	15
31	25	69	15	107	0
32	32	70	15	108	0
33	18	71	22	109	0
34	18	72	50	110	0
35	18	73	18	111	0
36	18	74	22	112	0
37	32	75	22	113	0
38	18	76	22	114	0

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SUBJECT 2 NONPREF-QUADS

****

TIME	%EMC	TIME	%EMC	TIME	%EMC
1	10	39	14	77	32
2	18	40	14	78	70
3	36	41	16	79	50
4	18	42	14	80	34
5	12	43	12	81	45
6	14	44	8	82	96
7	12	45	14	83	99
8	10	46	14	84	72
9	14	47	12	85	58
10	10	48	10	86	47
11	12	49	16	87	87
12	29	50	14	88	32
13	38	51	23	89	23
14	25	52	25	90	27
15	12	53	16	91	59
16	12	54	12	92	72
17	12	55	8	93	16
18	14	56	10	94	0
19	12	57	12	95	0
20	10	58	12	96	0
21	10	59	16	97	0
22	12	60	32	98	0
23	12	61	30	99	0
24	14	62	10	100	0
25	12	63	8	101	0
26	14	64	14	102	0
27	18	65	36	103	0
28	30	66	70	104	0
29	38	67	69	105	0
30	56	68	23	106	0
31	43	69	38	107	0
32	34	70	50	108	0
33	27	71	27	109	0
34	14	72	32	110	0
35	12	73	41	111	0
36	16	74	100	112	0
37	30	75	56	113	0
38	21	76	34	114	0

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SUBJECT 2 NONPREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	19	39	21	77	14
2	31	40	14	78	12
3	24	41	9	79	21
4	21	42	9	80	43
5	24	43	12	81	12
6	26	44	14	82	12
7	38	45	16	83	12
8	28	46	45	84	28
9	19	47	24	85	55
10	19	48	16	86	31
11	19	49	14	87	81
12	19	50	14	88	14
13	24	51	14	89	12
14	19	52	14	90	53
15	16	53	16	91	69
16	16	54	19	92	12
17	16	55	31	93	2
18	16	56	33	94	0
19	16	57	7	95	0
20	16	58	9	96	0
21	19	59	9	97	0
22	50	60	9	98	0
23	16	61	12	99	0
24	14	62	21	100	0
25	14	63	28	101	0
26	16	64	14	102	0
27	14	65	12	103	0
28	12	66	12	104	0
29	16	67	12	105	0
30	19	68	14	106	0
31	16	69	14	107	0
32	19	70	14	108	0
33	77	71	14	109	0
34	81	72	14	110	0
35	38	73	16	111	0
36	33	74	55	112	0
37	45	75	38	113	0
38	69	76	100	114	0

****

SUBJECT 2 NONPREF-TIB ANT

****

TIME	%EMG	TIME	%EMC	TIME	%EMG
1	33	39	45	77	0
2	33	40	37	78	0
3	41	41	33	79	0
4	33	42	41	80	0
5	37	43	33	81	0
6	37	44	56	82	0
7	33	45	37	83	25
8	29	46	25	84	72
9	33	47	29	85	25
10	41	48	25	86	29
11	33	49	21	87	53
12	10	50	21	88	6
13	10	51	18	89	56
14	14	52	10	90	33
15	18	53	25	91	0
16	18	54	18	92	0
17	18	55	18	93	0
18	18	56	18	94	0
19	14	57	18	95	0
20	14	58	18	96	0
21	18	59	25	97	0
22	14	60	14	98	0
23	14	61	10	99	0
24	18	62	6	100	0
25	14	63	0	101	0
26	14	64	2	102	0
27	18	65	0	103	0
28	33	66	0	104	0
29	33	67	0	105	0
30	25	68	0	106	0
31	33	69	0	107	0
32	49	70	2	108	0
33	49	71	0	109	0
34	100	72	2	110	0
35	84	73	37	111	0
36	49	74	18	112	0
37	41	75	0	113	0
38	41	76	0	114	0

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SUBJECT 2 PREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	10	39	17	77	13
2	18	40	27	78	13
3	11	41	14	79	42
4	10	42	7	80	51
5	10	43	6	81	28
6	10	44	8	82	17
7	8	45	8	83	38
8	10	46	8	84	16
9	14	47	8	85	23
10	10	48	8	86	48
11	8	49	10	87	61
12	8	50	11	88	100
13	10	51	20	89	28
14	11	52	8	90	31
15	11	53	7	91	45
16	21	54	8	92	31
17	17	55	8	93	17
18	11	56	8	94	17
19	11	57	10	95	30
20	11	58	18	96	14
21	11	59	21	97	0
22	11	60	17	98	0
23	11	61	11	99	0
24	13	62	10	100	0
25	20	63	13	101	0
26	21	64	20	102	0
27	17	65	16	103	0
28	13	66	8	104	0
29	8	67	8	105	0
30	8	68	8	106	0
31	6	69	10	107	0
32	8	70	10	108	0
33	8	71	11	109	0
34	6	72	11	110	0
35	7	73	37	111	0
36	8	74	17	112	0
37	8	75	13	113	0
38	8	76	30	114	0

****

SUBJECT 2 PREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	9	39	16	77	9
2	12	40	16	78	9
3	12	41	16	79	16
4	12	42	16	80	34
5	14	43	14	81	29
6	14	44	19	82	12
7	12	45	34	83	46
8	12	46	29	84	19
9	14	47	12	85	9
10	14	48	14	86	59
11	12	49	16	87	31
12	12	50	14	88	54
13	9	51	14	89	16
14	31	52	16	90	12
15	19	53	24	91	16
16	12	54	24	92	16
17	14	55	14	93	71
18	14	56	14	94	100
19	14	57	14	95	19
20	66	58	12	96	14
21	31	59	14	97	0
22	14	60	14	98	0
23	16	61	14	99	0
24	36	62	12	100	0
25	29	63	12	101	0
26	26	64	14	102	0
27	46	65	12	103	0
28	81	66	19	104	0
29	41	67	12	105	0
30	26	68	12	106	0
31	29	69	9	107	0
32	21	70	9	108	0
33	41	71	7	109	0
34	16	72	4	110	0
35	26	73	4	111	0
36	19	74	7	112	0
37	16	75	9	113	0
38	14	76	7	114	0

****

SUBJECT 2 PREF-TIE ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	6	39	24	77	12
2	9	40	15	78	18
3	12	41	12	79	15
4	9	42	15	80	15
5	12	43	12	81	12
6	38	44	15	82	18
7	27	45	15	83	9
8	15	46	9	84	12
9	15	47	12	85	15
10	15	48	15	86	24
11	18	49	15	87	27
12	29	50	21	88	35
13	35	51	12	89	21
14	18	52	12	90	9
15	18	53	12	91	27
16	15	54	9	92	71
17	18	55	9	93	0
18	18	56	12	94	3
19	29	57	15	95	3
20	21	58	6	96	3
21	21	59	3	97	0
22	21	60	3	98	0
23	21	61	6	99	0
24	18	62	9	100	0
25	18	63	9	101	0
26	27	64	12	102	0
27	32	65	9	103	0
28	44	66	9	104	0
29	100	67	15	105	0
30	56	68	12	106	0
31	24	69	24	107	0
32	24	70	56	108	0
33	24	71	38	109	0
34	18	72	12	110	0
35	29	73	3	111	0
36	35	74	12	112	0
37	47	75	12	113	0
38	29	76	6	114	0

****

SUBJECT 3 NONPREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	5	39	15	77	0
2	7	40	12	78	15
3	7	41	9	79	0
4	7	42	12	80	0
5	9	43	10	81	0
6	9	44	9	82	0
7	9	45	9	83	0
8	7	46	9	84	0
9	17	47	9	85	0
10	15	48	7	86	0
11	10	49	10	87	0
12	7	50	15	88	0
13	5	51	26	89	0
14	5	52	27	90	0
15	7	53	22	91	0
16	7	54	14	92	0
17	7	55	14	93	0
18	5	56	14	94	0
19	5	57	36	95	0
20	5	58	22	96	0
21	9	59	26	97	0
22	14	60	21	98	0
23	12	61	36	99	0
24	7	62	27	100	0
25	12	63	19	101	0
26	12	64	14	102	0
27	12	65	24	103	0
28	27	66	49	104	0
29	53	67	37	105	0
30	41	68	73	106	0
31	24	69	100	107	0
32	22	70	96	108	0
33	24	71	34	109	0
34	36	72	2	110	0
35	39	73	9	111	0
36	14	74	5	112	0
37	14	75	22	113	0
38	17	76	2	114	0

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SUBJECT 3 NONPREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	13	39	14	77	22
2	14	40	28	78	20
3	16	41	13	79	20
4	11	42	14	80	0
5	7	43	13	81	0
6	9	44	9	82	0
7	9	45	11	83	0
8	34	46	11	84	0
9	36	47	13	85	0
10	14	48	13	86	0
11	9	49	13	87	0
12	9	50	13	88	0
13	13	51	20	89	0
14	9	52	22	90	0
15	7	53	30	91	0
16	9	54	40	92	0
17	11	55	36	93	0
18	14	56	57	94	0
19	14	57	47	95	0
20	14	58	51	96	0
21	16	59	38	97	0
22	22	60	80	98	0
23	40	61	34	99	0
24	32	62	70	100	0
25	26	63	88	101	0
26	22	64	76	102	0
27	41	65	38	103	0
28	65	66	76	104	0
29	41	67	63	105	0
30	26	68	99	106	0
31	22	69	100	107	0
32	28	70	43	108	0
33	40	71	38	109	0
34	34	72	53	110	0
35	24	73	45	111	0
36	13	74	18	112	0
37	14	75	36	113	0
38	14	76	24	114	0

****

SUBJECT 3 NONPREF-TID ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	21	39	21	77	30
2	21	40	21	78	0
3	21	41	26	79	0
4	21	42	44	80	0
5	21	43	21	81	0
6	35	44	12	82	0
7	17	45	17	83	0
8	12	46	12	84	0
9	12	47	12	85	0
10	17	48	12	86	0
11	17	49	17	87	0
12	26	50	21	88	0
13	21	51	39	89	0
14	21	52	30	90	0
15	21	53	21	91	0
16	21	54	17	92	0
17	21	55	30	93	0
18	17	56	53	94	0
19	26	57	26	95	0
20	21	58	39	96	0
21	26	59	26	97	0
22	21	60	26	98	0
23	30	61	30	99	0
24	21	62	26	100	0
25	26	63	39	101	0
26	53	64	17	102	0
27	100	65	8	103	0
28	44	66	17	104	0
29	21	67	17	105	0
30	17	68	80	106	0
31	21	69	67	107	0
32	12	70	26	108	0
33	17	71	35	109	0
34	21	72	85	110	0
35	21	73	0	111	0
36	21	74	8	112	0
37	21	75	0	113	0
38	21	76	0	114	0

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SUBJECT 3 PREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	12	39	13	77	2
2	13	40	13	78	0
3	25	41	13	79	0
4	15	42	13	80	0
5	12	43	17	81	0
6	9	44	14	82	0
7	13	45	14	83	0
8	10	46	12	84	0
9	10	47	10	85	0
10	13	48	9	86	0
11	14	49	8	87	0
12	17	50	8	88	0
13	12	51	9	89	0
14	10	52	10	90	0
15	10	53	13	91	0
16	12	54	12	92	0
17	10	55	14	93	0
18	12	56	29	94	0
19	12	57	18	95	0
20	13	58	23	96	0
21	13	59	15	97	0
22	13	60	30	98	0
23	13	61	13	99	0
24	15	62	10	100	0
25	29	63	14	101	0
26	21	64	33	102	0
27	18	65	22	103	0
28	17	66	21	104	0
29	21	67	61	105	0
30	17	68	81	106	0
31	14	69	100	107	0
32	13	70	43	108	0
33	13	71	13	109	0
34	14	72	17	110	0
35	19	73	12	111	0
36	15	74	12	112	0
37	13	75	8	113	0
38	14	76	1	114	0

****

SUBJECT 3 PREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	11	39	13	77	4
2	11	40	18	78	0
3	15	41	20	79	0
4	13	42	20	80	0
5	13	43	30	81	0
6	15	44	20	82	0
7	15	45	15	83	0
8	13	46	15	84	0
9	11	47	18	85	0
10	8	48	30	86	0
11	8	49	18	87	0
12	11	50	18	88	0
13	8	51	23	89	0
14	11	52	23	90	0
15	13	53	23	91	0
16	11	54	18	92	0
17	11	55	27	93	0
18	11	56	58	94	0
19	13	57	41	95	0
20	11	58	23	96	0
21	11	59	51	97	0
22	13	60	20	98	0
23	18	61	51	99	0
24	32	62	32	100	0
25	100	63	77	101	0
26	58	64	82	102	0
27	34	65	56	103	0
28	68	66	18	104	0
29	30	67	13	105	0
30	30	68	32	106	0
31	56	69	18	107	0
32	46	70	44	108	0
33	46	71	75	109	0
34	25	72	60	110	0
35	18	73	23	111	0
36	15	74	20	112	0
37	13	75	60	113	0
38	30	76	18	114	0

****

SUBJECT 3 PREF-TIF ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	24	39	19	77	24
2	24	40	19	78	0
3	24	41	16	79	0
4	30	42	16	80	0
5	30	43	19	81	0
6	27	44	24	82	0
7	27	45	22	83	0
8	33	46	22	84	0
9	58	47	22	85	0
10	33	48	19	86	0
11	24	49	19	87	0
12	24	50	19	88	0
13	24	51	22	89	0
14	24	52	24	90	0
15	22	53	24	91	0
16	24	54	24	92	0
17	24	55	33	93	0
18	36	56	64	94	0
19	44	57	52	95	0
20	24	58	36	96	0
21	27	59	33	97	0
22	27	60	58	98	0
23	27	61	36	99	0
24	52	62	78	100	0
25	19	63	47	101	0
26	24	64	89	102	0
27	22	65	44	103	0
28	22	66	36	104	0
29	22	67	38	105	0
30	22	68	100	106	0
31	19	69	36	107	0
32	19	70	36	108	0
33	19	71	30	109	0
34	22	72	47	110	0
35	22	73	30	111	0
36	19	74	47	112	0
37	16	75	27	113	0
38	16	76	27	114	0

****

SUBJECT 4 NONPREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	4	39	10	77	25
2	7	40	10	78	0
3	7	41	12	79	0
4	11	42	14	80	0
5	8	43	13	81	0
6	8	44	25	82	0
7	7	45	18	83	0
8	8	46	17	84	0
9	19	47	25	85	0
10	13	48	42	86	0
11	10	49	66	87	0
12	13	50	57	88	0
13	14	51	36	89	0
14	11	52	27	90	0
15	8	53	19	91	0
16	6	54	15	92	0
17	10	55	12	93	0
18	19	56	42	94	0
19	36	57	64	95	0
20	50	58	47	96	0
21	40	59	72	97	0
22	30	60	92	98	0
23	26	61	37	99	0
24	19	62	41	100	0
25	12	63	67	101	0
26	8	64	100	102	0
27	7	65	97	103	0
28	6	66	44	104	0
29	8	67	34	105	0
30	10	68	40	106	0
31	17	69	23	107	0
32	14	70	37	108	0
33	8	71	18	109	0
34	10	72	17	110	0
35	13	73	19	111	0
36	10	74	17	112	0
37	12	75	17	113	0
38	12	76	21	114	0

****

SUBJECT 4 NONPREF - HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	8	39	10	77	51
2	10	40	21	78	0
3	10	41	16	79	0
4	30	42	21	80	0
5	24	43	21	81	0
6	13	44	73	82	0
7	10	45	16	83	0
8	8	46	21	84	0
9	2	47	19	85	0
10	8	48	27	86	0
11	10	49	43	87	0
12	10	50	35	88	0
13	21	51	24	89	0
14	10	52	43	90	0
15	13	53	62	91	0
16	13	54	98	92	0
17	16	55	100	93	0
18	16	56	57	94	0
19	24	57	59	95	0
20	49	58	59	96	0
21	100	59	43	97	0
22	76	60	24	98	0
23	65	61	13	99	0
24	81	62	8	100	0
25	46	63	10	101	0
26	40	64	24	102	0
27	73	65	16	103	0
28	43	66	13	104	0
29	59	67	10	105	0
30	51	68	10	106	0
31	24	69	10	107	0
32	70	70	24	108	0
33	16	71	51	109	0
34	16	72	79	110	0
35	19	73	54	111	0
36	13	74	21	112	0
37	24	75	43	113	0
38	30	76	79	114	0

****

SUBJECT 4 NONPREF-TIP ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	6	39	70	77	31
2	11	40	81	78	0
3	8	41	59	79	0
4	8	42	39	80	0
5	8	43	22	81	0
6	11	44	25	82	0
7	11	45	31	83	0
8	11	46	25	84	0
9	25	47	33	85	0
10	28	48	36	86	0
11	25	49	47	87	0
12	31	50	50	88	0
13	70	51	36	89	0
14	56	52	31	90	0
15	33	53	42	91	0
16	28	54	39	92	0
17	36	55	31	93	0
18	25	56	36	94	0
19	67	57	22	95	0
20	92	58	20	96	0
21	50	59	31	97	0
22	20	60	42	98	0
23	17	61	33	99	0
24	25	62	50	100	0
25	20	63	100	101	0
26	25	64	64	102	0
27	25	65	70	103	0
28	33	66	47	104	0
29	59	67	33	105	0
30	39	68	25	106	0
31	17	69	42	107	0
32	17	70	53	108	0
33	22	71	45	109	0
34	22	72	36	110	0
35	22	73	59	111	0
36	20	74	36	112	0
37	28	75	31	113	0
38	36	76	25	114	0

****

SUBJECT 4 PREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMC
1	5	39	6	77	0
2	10	40	6	78	0
3	9	41	8	79	0
4	8	42	6	80	0
5	10	43	14	81	0
6	6	44	30	82	0
7	9	45	13	83	0
8	9	46	8	84	0
9	6	47	5	85	0
10	6	48	11	86	0
11	8	49	10	87	0
12	10	50	9	88	0
13	21	51	9	89	0
14	40	52	11	90	0
15	31	53	10	91	0
16	20	54	11	92	0
17	13	55	27	93	0
18	14	56	41	94	0
19	10	57	15	95	0
20	11	58	10	96	0
21	10	59	9	97	0
22	10	60	13	98	0
23	10	61	13	99	0
24	10	62	11	100	0
25	8	63	14	101	0
26	9	64	18	102	0
27	6	65	39	103	0
28	8	66	75	104	0
29	6	67	100	105	0
30	8	68	93	106	0
31	8	69	68	107	0
32	8	70	14	108	0
33	8	71	24	109	0
34	16	72	14	110	0
35	6	73	15	111	0
36	5	74	11	112	0
37	6	75	5	113	0
38	8	76	0	114	0

****

SUBJECT 4 PREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	3	39	17	77	0
2	1	40	19	78	0
3	11	41	19	79	0
4	9	42	27	80	0
5	5	43	23	81	0
6	3	44	21	82	0
7	7	45	21	83	0
8	9	46	21	84	0
9	13	47	19	85	0
10	21	48	25	86	0
11	33	49	25	87	0
12	51	50	37	88	0
13	17	51	41	89	0
14	45	52	33	90	0
15	57	53	77	91	0
16	31	54	63	92	0
17	41	55	51	93	0
18	37	56	31	94	0
19	21	57	33	95	0
20	27	58	35	96	0
21	17	59	49	97	0
22	47	60	35	98	0
23	19	61	61	99	0
24	15	62	21	100	0
25	15	63	17	101	0
26	15	64	23	102	0
27	19	65	19	103	0
28	47	66	27	104	0
29	23	67	41	105	0
30	17	68	19	106	0
31	17	69	71	107	0
32	15	70	100	108	0
33	19	71	37	109	0
34	27	72	41	110	0
35	19	73	15	111	0
36	19	74	23	112	0
37	19	75	21	113	0
38	17	76	0	114	0

****

SUBJECT 4 PREF-TIB ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	7	39	16	77	0
2	10	40	19	78	0
3	10	41	19	79	0
4	7	42	19	80	0
5	7	43	19	81	0
6	7	44	19	82	0
7	7	45	19	83	0
8	7	46	24	84	0
9	7	47	22	85	0
10	7	48	19	86	0
11	10	49	19	87	0
12	16	50	24	88	0
13	38	51	24	89	0
14	36	52	38	90	0
15	64	53	33	91	0
16	75	54	30	92	0
17	55	55	27	93	0
18	36	56	61	94	0
19	33	57	22	95	0
20	22	58	19	96	0
21	19	59	22	97	0
22	22	60	24	98	0
23	24	61	19	99	0
24	24	62	16	100	0
25	22	63	16	101	0
26	22	64	30	102	0
27	24	65	64	103	0
28	24	66	100	104	0
29	22	67	41	105	0
30	19	68	36	106	0
31	19	69	16	107	0
32	19	70	16	108	0
33	19	71	16	109	0
34	19	72	16	110	0
35	19	73	7	111	0
36	19	74	16	112	0
37	16	75	16	113	0
38	16	76	0	114	0

****

SUBJECT 5 NONPREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	4	39	11	77	74
2	5	40	10	78	100
3	5	41	9	79	28
4	4	42	7	80	38
5	5	43	7	81	15
6	10	44	7	82	11
7	6	45	7	83	10
8	6	46	7	84	9
9	6	47	7	85	0
10	6	48	7	86	0
11	6	49	7	87	0
12	6	50	7	88	0
13	15	51	7	89	0
14	9	52	7	90	0
15	7	53	10	91	0
16	10	54	7	92	0
17	7	55	7	93	0
18	13	56	11	94	0
19	15	57	16	95	0
20	17	58	28	96	0
21	15	59	35	97	0
22	29	60	43	98	0
23	45	61	35	99	0
24	25	62	30	100	0
25	19	63	61	101	0
26	10	64	37	102	0
27	9	65	17	103	0
28	10	66	15	104	0
29	9	67	25	105	0
30	16	68	41	106	0
31	11	69	23	107	0
32	9	70	31	108	0
33	9	71	36	109	0
34	9	72	36	110	0
35	10	73	58	111	0
36	7	74	22	112	0
37	7	75	35	113	0
38	9	76	28	114	0

****

SUBJECT 5 NONPREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	4	39	20	77	34
2	7	40	45	78	65
3	7	41	27	79	52
4	7	42	16	80	100
5	7	43	11	81	36
6	7	44	13	82	27
7	7	45	13	83	18
8	7	46	16	84	13
9	7	47	18	85	0
10	7	48	16	86	0
11	7	49	18	87	0
12	7	50	47	88	0
13	7	51	29	89	0
14	7	52	16	90	0
15	9	53	18	91	0
16	9	54	20	92	0
17	9	55	20	93	0
18	16	56	20	94	0
19	65	57	18	95	0
20	52	58	40	96	0
21	25	59	36	97	0
22	45	60	16	98	0
23	34	61	13	99	0
24	16	62	7	100	0
25	25	63	18	101	0
26	58	64	56	102	0
27	40	65	29	103	0
28	29	66	49	104	0
29	47	67	56	105	0
30	20	68	27	106	0
31	16	69	16	107	0
32	29	70	43	108	0
33	16	71	16	109	0
34	13	72	13	110	0
35	16	73	16	111	0
36	13	74	22	112	0
37	13	75	61	113	0
38	18	76	27	114	0

****

SUBJECT 5 NONPREF-TIP ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	39	39	32	77	32
2	35	40	39	78	23
3	32	41	32	79	61
4	35	42	32	80	100
5	39	43	39	81	13
6	39	44	35	82	35
7	39	45	55	83	13
8	32	46	45	84	13
9	39	47	52	85	0
10	39	48	42	86	0
11	39	49	39	87	0
12	35	50	42	88	0
13	32	51	39	89	0
14	29	52	39	90	0
15	26	53	35	91	0
16	29	54	32	92	0
17	29	55	29	93	0
18	19	56	35	94	0
19	19	57	39	95	0
20	29	58	32	96	0
21	26	59	32	97	0
22	61	60	32	98	0
23	48	61	26	99	0
24	29	62	26	100	0
25	23	63	19	101	0
26	23	64	19	102	0
27	19	65	16	103	0
28	26	66	13	104	0
29	26	67	16	105	0
30	26	68	52	106	0
31	26	69	32	107	0
32	23	70	32	108	0
33	26	71	13	109	0
34	29	72	13	110	0
35	32	73	16	111	0
36	32	74	52	112	0
37	32	75	100	113	0
38	26	76	13	114	0

****

SUBJECT 5 PREF-QUADS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	8	39	15	77	0
2	6	40	15	78	0
3	19	41	27	79	0
4	19	42	22	80	0
5	8	43	15	81	0
6	8	44	13	82	0
7	8	45	13	83	0
8	19	46	11	84	0
9	11	47	11	85	0
10	27	48	13	86	0
11	15	49	13	87	0
12	13	50	13	88	0
13	15	51	13	89	0
14	13	52	13	90	0
15	17	53	31	91	0
16	34	54	31	92	0
17	24	55	19	93	0
18	22	56	11	94	0
19	15	57	24	95	0
20	13	58	13	96	0
21	15	59	26	97	0
22	13	60	20	98	0
23	17	61	13	99	0
24	22	62	11	100	0
25	19	63	22	101	0
26	13	64	43	102	0
27	13	65	24	103	0
28	13	66	15	104	0
29	13	67	38	105	0
30	15	68	20	106	0
31	26	69	100	107	0
32	17	70	29	108	0
33	13	71	10	109	0
34	13	72	17	110	0
35	13	73	20	111	0
36	15	74	11	112	0
37	15	75	13	113	0
38	15	76	11	114	0

****

SUBJECT 5 PREF-HAMS

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	12	39	30	77	0
2	10	40	17	78	0
3	8	41	10	79	0
4	8	42	12	80	0
5	10	43	10	81	0
6	8	44	10	82	0
7	6	45	10	83	0
8	8	46	8	84	0
9	10	47	8	85	0
10	17	48	8	86	0
11	6	49	12	87	0
12	6	50	12	88	0
13	8	51	12	89	0
14	10	52	10	90	0
15	26	53	12	91	0
16	35	54	12	92	0
17	32	55	17	93	0
18	17	56	34	94	0
19	21	57	43	95	0
20	41	58	15	96	0
21	17	59	37	97	0
22	39	60	37	98	0
23	12	61	13	99	0
24	37	62	10	100	0
25	35	63	17	101	0
26	23	64	30	102	0
27	21	65	48	103	0
28	37	66	21	104	0
29	17	67	13	105	0
30	15	68	43	106	0
31	19	69	28	107	0
32	37	70	17	108	0
33	15	71	21	109	0
34	8	72	37	110	0
35	10	73	85	111	0
36	13	74	100	112	0
37	13	75	23	113	0
38	15	76	12	114	0

****

SUBJECT 5 PREF-TIB ANT

****

TIME	%EMG	TIME	%EMG	TIME	%EMG
1	47	39	31	77	0
2	43	40	28	78	0
3	43	41	24	79	0
4	43	42	28	80	0
5	43	43	28	81	0
6	43	44	35	82	0
7	43	45	35	83	0
8	39	46	31	84	0
9	39	47	35	85	0
10	39	48	35	86	0
11	31	49	31	87	0
12	31	50	28	88	0
13	35	51	20	89	0
14	31	52	20	90	0
15	31	53	20	91	0
16	43	54	24	92	0
17	73	55	28	93	0
18	54	56	24	94	0
19	47	57	20	95	0
20	47	58	31	96	0
21	47	59	24	97	0
22	43	60	16	98	0
23	35	61	16	99	0
24	28	62	28	100	0
25	31	63	50	101	0
26	39	64	28	102	0
27	43	65	24	103	0
28	43	66	31	104	0
29	31	67	31	105	0
30	28	68	43	106	0
31	24	69	92	107	0
32	20	70	65	108	0
33	20	71	43	109	0
34	28	72	99	110	0
35	24	73	100	111	0
36	24	74	39	112	0
37	28	75	39	113	0
38	31	76	28	114	0

APPENDIX F

COMPUTER PROGRAMS

```
0: % "ANGULAR ACCLERATION AND ANGULAR VELOCITY"
1: dsp "ANGULAR  KINEMATICS";wait 1500
2: ent "FILE # TO BE USED :",Q
3: dim A[20,28],B[20,28],D[27],O[8,20],Q[8,20],N$[4,22]
4: dim Z$[21,36],K$[14,11],R[20,14],R$[1,3],C$[2,66]
5: trk 1;ldf Q,A[*],B[*],D[*];ldf Q+1,Z$,K$;trk 0
6: ent "DEGREES [0] or RADIANS [1] ?",S
7: ent "COMMENT [up to 20 Characters]",C$[1]
8: if S=1;"rad"→R$[1];jmp 2
9: "deg"→R$[1]
10: prt " SEGMENT CODE";spc ;fmt ,f3.0,c13
11: for I=1 to 14
12: wrt 16,I,K$[I]
13: next I
14: spc 2;0→A
15: ent "NEXT SEGMENT TO OUTPUT? (0=STOP)",I;if I#0;jmp 3
16: if I=0;prt " CALCUL DONE";gsb "RECO"
17: gto 75
18: A+1→A;prt I;spc 2
19: sfg 14
20: for H=1 to D[27]-1
21: (A[H,I+14]-B[H,I+14])/(A[H,I]-B[H,I])→r0
22: (A[H+1,I+14]-B[H+1,I+14])/(A[H+1,I]-B[H+1,I])→r1
23: atn((r1-r0)/(1+r0r1))→R[H,I]
24: if S=1;R[H,I]/57.296→R[H,I]
25: next H
26: cfg 14
27: for H=1 to D[27]-1
28: R[H,I]/D[H+1]→A[H,I]
29: H→B;A[H,I]→O[A,B]
30: next H
31: for H=1 to D[27]-2
32: if H=1 or H=D[27]-2;(A[H+1,I]-A[H,I])/((D[H+1]+D[H+2])/2)→B[H,I];jmp 2
33: (A[H+1,I]-A[H-1,I])/((D[H+1]+D[H])/2)→B[H,I]
34: H→B;B[H,I]→O[A+4,B]
35: next H
36: ent "DO YOU NEED RAW DATA ? (1=YES)",P;if P#1;gto 15
37: wtb 7,10,10,10,10,10
38: fmt 1,14x,60"-",/;wrt 7.1
39: fmt 2,14x,c20,c15,c25,/;wrt 7.2,"ANGULAR KINEMATICS :",K$[I],C$[1]
40: wrt 7.1;fmt 3,/,/,14x,2c6,3c16;fmt 7,34x,c3,10x,c3,c4,8x,c3,c8,/,/
41: wrt 7.3,"FRAME#","TIME","DISPLACEMENT","VELOCITY   "," ACCELERATION"
42: wrt 7.7,R$[1],R$[1],"/sec",R$[1],"/sec/sec"
43: fmt 4,14x,f2.0;fmt 5,21x,f5.3,4x,f9.2,6x,f9.2
44: fmt 6,62x,f10.2
45: for H=1 to D[27]
46: wrt 7.4,H;if H<=D[27]-1;gsb "output"
47: next H
48: wtb 7,12;gto 15
49: "output":
50: wrt 7.5,D[H+1],R[H,I],A[H,I]
51: if H<D[27]-1;wrt 7.6,B[H,I];wtb 7,27,10
52: ret
53: "RECO":
54: 0→X
55: for H=2 to 17
56: X+D[H]→X
57: next H
58: 0→Y
59: for H=1 to 19
60: Y+D[H+1]→Y;Y-X→Q[1,H]→Q[2,H]→Q[3,H]→Q[4,H]
*27954
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```
61: next H
62: for H=1 to 18
63: (Q[1,H]+Q[1,H+1])/2→Q[5,H]→Q[6,H]→Q[7,H]→Q[8,H]
64: next H
65: ent "LEFT FOOT ?  (1=YES)",r20;if r20=1;gsb "LEFT"
66: ret
67: "LEFT":
68: for A=1 to 4;for B=1 to D[27]-1
69: (-1)O[A,B]→O[A,B]
70: next B;next A
71: for A=4 to 8;for B=1 to D[27]-2
72: (-1)O[A,B]→O[A,B]
73: next B;next A
74: ret
75: % " MULTIPLE PLOTS"
76: dim Y[8,20],X[8,20],P$[1]
77: "CONTACT"→N$[1];"TIME (s.)"→N$[2]
78: fxd 2;ent "VELOCITY (1=YES) or AC/TION (0=YES)",E;if E=1;gsb "VELO"
79: if E=0;gsb "ACCE"
80: gsb "PLOT"
81: gsb "VertL"
82: wtb 7,12;jmp -4
83: end
84: "PLOT":
85: gsb "PMIN"
86: ent "MIN Y",r3;ent "MAX Y",r2;ent "MAX X",r0;ent "MIN X",r1
87: gsb "PMIN"
88: if r1<0 and r0>0;r0+abs(r1)→r5
89: if r1>0;r0-r1→r5
90: if r1=0;r0→r5;300→X
91: if r3<0 and r2>0;r2+abs(r3)→r6
92: if r3>0;r2-r3→r6
93: if r3=0;r2→r6;450→Y
94: 17→r11;14→r12
95: 47.2r11→r11;37.8r12→r12;r11/47.2r5→r13;r12/37.8r6→r14
96: if r1<0;300+abs(47.2r1r13)→X
97: if r3<0;450+abs(37.8r3r14)→Y
98: if r1>=0;300→X
99: if r3>=0;450→Y
100: wtb 7,27,79,int(X/64),int(X),int(Y/64),int(Y)
101: r0r13*47.2→O;r1r13*47.2→P;r2r14*37.8→Q;r3r14*37.8→R
102: if r1>=0;0→P;O-47.2r1r13→O
103: if r3>=0;0→R;Q-37.8r3r14→Q
104: wtb 7,27,46,"|",int(10/64),int(10),0
105: wtb 7,27,65,int(O/64),int(O),int(Q/64),int(Q);if flg1;cfg 1;jmp 2
106: wtb 7,27,10,8,8,8,8;wrt 7,N$[1];sfg 1;jmp -1
107: wtb 7,27,97,int(O/64),int(O),int(R/64),int(R)
108: wtb 7,27,46,char(95),int(10/64),int(10),9
109: wtb 7,27,65,int(P/64),int(P),int(O/64),int(O)
110: wtb 7,27,97,int(O/64),int(O),int(O/64),int(O);wrt 7,"  ",N$[2]
111: for A=1 to r10
112: for B=1 to F
113: Y[A,B]37.8r14→Y[A,B]
114: if r3>0;Y[A,B]-37.8r3r14→Y[A,B]
115: X[A,B]47.2r13→X[A,B]
116: if r1>0;X[A,B]-47.2r1r13→X[A,B]
117: next B
118: next A
119: for A=1 to r10
120: ent "NEXT POINT TO PLOT= [0=STOP]",A
*9620
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121: if A=0 or A>r10;gto 131
122: ent "PLOTCHARACTER=",P$[1]
123: ent "PLOTDENSITY =",U
124: wtb 7,27,46,P$[1],int(U/64),int(U),0
125: wtb 7,27,65,int(X[A,1]/64),int(X[A,1]),int(Y[A,1]/64),int(Y[A,1])
126: for B=2 to F
127: wtb 7,27,97,int(X[A,B]/64),int(X[A,B]),int(Y[A,B]/64),int(Y[A,B])
128: next B
129: fxd 0;fmt 3,8x,c;wrt 16.3,P$[1];prt " PD",U;prt " P#",A;spc 2
130: next A
131: ent "MIN. Y LABEL",r16;ent "MAX. Y LABEL",r17;ent "Y LABEL INCREMENT",r18
132: if X#300 or Y#450;gsb "XY"
133: fmt ,f7.0,c;37.8r14r16→L;r16→K
134: if r3>0;L-37.8r3r14→L
135: wtb 7,27,65,int(-(104-P)/64),int(-(104-P)),int(L/64),int(L)
136: wrt 7,K," -";K+r18→K;L+37.8r14r18→L
137: if K<=r17;jmp -2
138: ent "MIN X LABEL",r16;ent "MAX X LABEL",r17;ent "X LABEL INCREMENT",r18
139: fmt ,f5.2;47.2r13r16→L;r16→K
140: if r1>0;L-47.2r1r13→L
141: wtb 7,27,65,int(L/64),int(L),int(R/64),int(R);wrt 7,"|"
142: wtb 7,27,65,int((L-24)/64),int(L-24),int(-(20-R)/64),int(-(20-R))
143: wrt 7,K;K+r18→K;L+47.2r13r18→L
144: if K<=r17;jmp -3
145: wtb 7,27,65,int(P/64),int(P),int((R-50)/64),int(R-50)
146: ent "TITLE",C$[2]
147: fmt ,c;wrt 7,C$[2]
148: ret
149: "XY":
150: wtb 7,27,65,int(P/64),int(P),int(Q/64),int(Q)
151: wtb 7,27,46,"|",int(10/64),int(10),0
152: wtb 7,27,97,int(P/64),int(P),int(R/64),int(R)
153: wtb 7,27,46,char(95),int(10/64),int(10),9
154: wtb 7,27,97,int(O/64),int(O),int(R/64),int(R)
155: ret
156: "PMIN":
157: prt " MIN Y",r3;prt " MAX Y",r2;prt " MIN X",r1;prt " MAX X",r0;spc 2
158: ret
159: "VertL":
160: ent "NAME OF Y AXIS",N$[3]
161: wtb 7,27,65,int((P-110)/64),int(P-110),int((Q-150)/64),int(Q-150)
162: wtb 7,27,77;fmt x,c
163: for A=1 to 22
164: wrt 7,N$[3,A,A]
165: next A
166: ret
167: "VELO":
168: 4→P→r10;19→Q→F
169: for A=1 to 4;for B=1 to 19
170: O[A,B]→Y[A,B];Q[A,B]→X[A,B]
171: next B;next A
172: min(X[*])→r1;max(X[*])→r0;min(Y[*])→r3;max(Y[*])→r2
173: ret
174: "ACCE":
175: 4→P→r10;18→Q→F
176: for A=1 to 4;for B=1 to 18
177: O[A+4,B]→Y[A,B];Q[A+4,B]→X[A,B]
178: next B;next A
179: min(X[*])→r1;max(X[*])→r0;min(Y[*])→r3;max(Y[*])→r2
180: ret
*11005
```

```
0: dsp "LINEAR VELS OF DISTAL ENDPOINTS";wait 1500
1: ent "FILE # TO BE USED :",Q
2: ent "Right Side[1]or Left Side[2]?",S
3: dim A[20,28],B[20,28],D[27],Z$[21,36],K$[14,11],R[20,14]
4: dim C$[2,66],N$[4,22]
5: trk 1;ldf Q,A[*],B[*],D[*];ldf Q+1,Z$,K$;trk 0
6: ent "COMMENT [up to 20 Characters]",C$[1]
7: if S=1;"RIGHT SIDE:"→K$[1]
8: if S=2;"LEFT SIDE:"→K$[2]
9: for I=1 to 14
10: for H=1 to D[27]-1
11: √((B[H+1,I]-B[H,I])^2+(B[H+1,I+14]-B[H,I+14])^2)→R[H,I]
12: R[H,I]*D[1]/(100*D[H+1])→R[H,I]
13: next H
14: next I
15: ent "DO YOU NEED RAW DATA? (0=NO)",P;if P=0;gto 24
16: wtb 7,10,10,10,10,10,10
17: fmt 1,14x,60"-",/;wrt 7.1
18: fmt 2,14x,c60,/
19: wrt 7.2,"LINEAR VELOCITY DISTAL END POINTS FOR THIGH,LEG & FOOT."
20: fmt 3,14x,c22,c11,c25,/;wrt 7.3,"IN m/sec FOR THE ",K$[S],C$[1]
21: wrt 7.1
22: fmt 5,14x,c6,4c16,/;wrt 7.5,"FRAME#","HIP","KNEE ","ANKLE","TOE"
23: fmt 4,14x,f2.0,/,f36.2,3f16.2
24: if S=1;2→A;9→B;10→C;11→Z
25: if S=2;2→A;12→B;13→C;14→Z
26: if P=0;gto 30
27: for H=1 to D[27]-1
28: wrt 7.4,H,R[H,A],R[H,B],R[H,C],R[H,Z]
29: next H;wtb 7,12
30: % " MULTIPLE PLOTS"
31: 4→P→r10;19→Q→F
32: dim Y[4,19],X[4,19],P$[1]
33: for H=1 to 19
34: R[H,A]→Y[1,H];R[H,B]→Y[2,H]
35: R[H,C]→Y[3,H];R[H,Z]→Y[4,H]
36: next H
37: 0→X
38: for H=2 to 17
39: X+D[H]→X
40: next H
41: 0→Y
42: for H=1 to 19
43: Y+D[H+1]→Y;Y-X→X[1,H]→X[2,H]→X[3,H]→X[4,H]
44: next H
45: "CONTACT"→N$[1];"TIME (s.)"→N$[2]
46: fxd 2
47: gsb "PLOT"
48: gsb "VertL"
49: end
50: "PLOT":
51: min(X[*])→r1;max(X[*])→r0;min(Y[*])→r3;max(Y[*])→r2
52: gsb "PMIN"
53: ent "MIN Y",r3;ent "MAX Y",r2;ent "MAX X",r0;ent "MIN X",r1
54: gsb "PMIN"
55: if r1<0 and r0>0;r0+abs(r1)→r5
56: if r1>0;r0-r1→r5
57: if r1=0;r0→r5;300→X
58: if r3<0 and r2>0;r2+abs(r3)→r6
59: if r3>0;r2-r3→r6
60: if r3=0;r2→r6;450→Y
*6556
```

```
61: 17→r11;14→r12
62: 47.2r11→r11;37.8r12→r12;r11/47.2r5→r13;r12/37.8r6→r14
63: if r1<0;300+abs(47.2r1r13)→X
64: if r3<0;450+abs(37.8r3r14)→Y
65: if r1>=0;300→X
66: if r3>=0;450→Y
67: wtb 7,27,79,int(X/64),int(X),int(Y/64),int(Y)
68: r0r13*47.2→O;r1r13*47.2→P;r2r14*37.8→Q;r3r14*37.8→R
69: if r1>=0;0→P;O-47.2r1r13→O
70: if r3>=0;0→R;Q-37.8r3r14→Q
71: wtb 7,27,46,"|",int(10/64),int(10),0
72: wtb 7,27,65,int(O/64),int(O),int(Q/64),int(Q);if flg1;cfg 1;jmp 2
73: wtb 7,27,10,8,8,8,8;wrt 7,N$[1];sfg 1;jmp -1
74: wtb 7,27,97,int(O/64),int(O),int(R/64),int(R)
75: wtb 7,27,46,char(95),int(10/64),int(10),9
76: wtb 7,27,65,int(P/64),int(P),int(O/64),int(O)
77: wtb 7,27,97,int(O/64),int(O),int(0/64),int(0);wrt 7,"  ",N$[2]
78: for A=1 to r10
79: for B=1 to F
80: Y[A,B]37.8r14→Y[A,B]
81: if r3>0;Y[A,B]-37.8r3r14→Y[A,B]
82: X[A,B]47.2r13→X[A,B]
83: if r1>0;X[A,B]-47.2r1r13→X[A,B]
84: next B
85: next A
86: for A=1 to r10
87: ent "NEXT POINT TO PLOT= [0=STOP]",A
88: if A=0 or A>r10;gto 98
89: ent "PLOTCHARACTER=",P$[1]
90: ent "PLOTDENSITY =",U
91: wtb 7,27,46,P$[1],int(U/64),int(U),0
92: wtb 7,27,65,int(X[A,1]/64),int(X[A,1]),int(Y[A,1]/64),int(Y[A,1])
93: for B=2 to F
94: wtb 7,27,97,int(X[A,B]/64),int(X[A,B]),int(Y[A,B]/64),int(Y[A,B])
95: next B
96: fxd 0;fmt 3,8x,c;wrt 16.3,P$[1];prt " PD",U;prt " P#",A;spc 2
97: next A
98: ent "MIN. Y LABEL",r16;ent "MAX. Y LABEL",r17;ent "Y LABEL INCREMENT",r18
99: if X#300 or Y#450;gsb "XY"
100: fmt ,f6.0,c;37.8r14r16→L;r16→K
101: if r3>0;L-37.8r3r14→L
102: wtb 7,27,65,int(-(104-P)/64),int(-(104-P)),int(L/64),int(L)
103: wrt 7,K,"  -";K+r18→K;L+37.8r14r18→L
104: if K<=r17;jmp -2
105: ent "MIN X LABEL",r16;ent "MAX X LABEL",r17;ent "X LABEL INCREMENT",r18
106: fmt ,f5.2;47.2r13r16→L;r16→K
107: if r1>0;L-47.2r1r13→L
108: wtb 7,27,65,int(L/64),int(L),int(R/64),int(R);wrt 7,"|"
109: wtb 7,27,65,int((L-24)/64),int(L-24),int(-(20-R)/64),int(-(20-R))
110: wrt 7,K;K+r18→K;L+47.2r13r18→L
111: if K<=r17;jmp -3
112: wtb 7,27,65,int(P/64),int(P),int((R-50)/64),int(R-50)
113: ent "TITLE",C$[2]
114: fmt ,c;wrt 7,C$[2]
115: ret
116: "XY":
117: wtb 7,27,65,int(P/64),int(P),int(Q/64),int(Q)
118: wtb 7,27,46,"|",int(10/64),int(10),0
119: wtb 7,27,97,int(P/64),int(P),int(R/64),int(R)
120: wtb 7,27,46,char(95),int(10/64),int(10),9
*5145
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121: wtb 7,27,97,int(O/64),int(O),int(P/64),int(P)
122: ret
123: "PMIN":
124: prt " MIN Y",r3;prt " MAX Y",r2;prt " MIN X",r1;prt " MAX X",r0;spc
125: ret
126: "VertL":
127: ent "NAME OF Y AXIS",N$[3]
128: wtb 7,27,65,int((P-110)/64),int(P-110),int((Q-120)/64),int(Q-120)
129: wtb 7,27,77;fmt x,c
130: for A=1 to 22
131: wrt 7,N$[3,A,A]
132: next A
133: ret
*14606
```

```
0: % "VELOCITY OF CENTRE OF MASS"
1: dsp "CM [X,Y,DIPLACEMENT,VELOCITY]";wait 1500
2: dim A[20,28],B[20,28],D[27],S[14],M[14],Z[2,20],V[3,19],Z$[3,1]
3: dim K$[1,50],O[2,19],Q[1,19]
4: "."→Z$[1];","→Z$[2];"*"→Z$[3]
5: .5→S[1]→S[2];.436→S[3]→S[6];.43→S[4]→S[7];.28→S[5]→S[8]
6: .433→S[9]→S[10]→S[12]→S[13];.45→S[11]→S[14]
7: .096→M[1];.458→M[2];.033→M[3]→M[6];.019→M[4]→M[7];.0065→M[5]→M[8]
8: .105→M[9]→M[12];.045→M[10]→M[13];.0145→M[11]→M[14]
9: ent "FILE # TO BE USED ?",Q
10: trk 1
11: ldf Q,A[*],B[*],D[*]
12: trk 0
13: for H=1 to D[27];0→T→U
14: for I=1 to 14
15: A[H,I]-B[H,I]→O;abs(O)→O;A[H,I+14]-B[H,I+14]→P;abs(P)→P
16: S[I]O→K;S[I]P→L
17: if A[H,I]<B[H,I];K+A[H,I]→E;gto 19
18: A[H,I]-K→E
19: if A[H,I+14]<B[H,I+14];L+A[H,I+14]→F;gto 21
20: A[H,I+14]-L→F
21: M[I]E→C;M[I]F→D;C+T→R;D+U→Q;R→T;Q→U
22: next I
23: R→Z[1,H];Q→Z[2,H];if H=1;R→r7
24: if R>r7;R→r7
25: if Q>r7;Q→r7
26: if H>1;gsb "cmout"
27: next H
28: ent "PREF. (1) or NONPREF.(0)",r20;if r20=1;1→A
29: if r20=0;2→A
30: for H=1 to D[27]-1
31: if H=1 or H=D[27]-1;V[3,H]→O[A,H];jmp 2
32: (V[3,H+1]D[H+2]+V[3,H-1]D[H+1])/(D[H+1]+D[H+2])→O[A,H]
33: next H
34: if r20=1;gto 9
35: 0→X
36: for H=2 to 17
37: X+D[H]→X
38: next H
39: 0→Y
40: for H=1 to 19
41: Y+D[H+1]→Y;Y-X→Q[1,H]
42: next H
43: wait 2000;beep
44: gto 51
45: "cmout":
46: (Z[1,H]-Z[1,H-1])D[1]/100→r1
47: (Z[2,H]-Z[2,H-1])D[1]/100→r2
48: √(r1^2+r2^2)→r3;r1/D[H]→r4;r2/D[H]→r5;r3/D[H]→r6
49: r4→V[1,H-1];r5→V[2,H-1];r6→V[3,H-1]
50: ret
51: % " MULTIPLE PLOTS"
52: dim Y[2,19],X[2,19],P$[1],N$[3,20]
53: "CONTACT"→N$[1];"TIME (s.)"→N$[2]
54: for H=1 to 19
55: O[1,H]→Y[1,H];O[2,H]→Y[2,H];Q[1,H]→X[1,H]→X[2,H]
56: next H
57: 2→P→r10;19→Q→F
58: gsb "PLOT"
59: gsb "VertL"
60: wtb 7,12;end
*9268
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```
61: "PLOT":
62: min(X[*])→r1;max(X[*])→r0;min(Y[*])→r3;max(Y[*])→r2
63: gsb "PMIN"
64: ent "MIN Y",r3;ent "MAX Y",r2;ent "MAX X",r0;ent "MIN X",r1
65: gsb "PMIN"
66: if r1<0 and r0>0;r0+abs(r1)→r5
67: if r1>0;r0-r1→r5
68: if r1=0;r0→r5;300→X
69: if r3<0 and r2>0;r2+abs(r3)→r6
70: if r3>0;r2-r3→r6
71: if r3=0;r2→r6;450→Y
72: 17→r11;14→r12
73: 47.2r11→r11;37.8r12→r12;r11/47.2r5→r13;r12/37.8r6→r14
74: if r1<0;300+abs(47.2r1r13)→X
75: if r3<0;450+abs(37.8r3r14)→Y
76: if r1>=0;300→X
77: if r3>=0;450→Y
78: wtb 7,27,79,int(X/64),int(X),int(Y/64),int(Y)
79: r0r13*47.2→O;r1r13*47.2→P;r2r14*37.8→Q;r3r14*37.8→R
80: if r1>=0;0→P;O-47.2r1r13→O
81: if r3>=0;0→R;Q-37.8r3r14→Q
82: wtb 7,27,46,"|",int(10/64),int(10),0
83: wtb 7,27,65,int(0/64),int(0),int(Q/64),int(Q);if flg1;cfg 1;jmp 2
84: wtb 7,27,10,8,8,8,8;wrt 7,N$[1];sfg 1;jmp -1
85: wtb 7,27,97,int(0/64),int(0),int(R/64),int(R)
86: wtb 7,27,46,char(95),int(10/64),int(10),9
87: wtb 7,27,65,int(P/64),int(P),int(0/64),int(0)
88: wtb 7,27,97,int(O/64),int(O),int(0/64),int(0);wrt 7,"  ",N$[2]
89: for A=1 to r10
90: for B=1 to F
91: Y[A,B]37.8r14→Y[A,B]
92: if r3>0;Y[A,B]-37.8r3r14→Y[A,B]
93: X[A,B]47.2r13→X[A,B]
94: if r1>0;X[A,B]-47.2r1r13→X[A,B]
95: next B
96: next A
97: for A=1 to r10
98: ent "NEXT POINT TO PLOT= [0=STOP]",A
99: if A=0 or A>r10;gto 109
100: ent "PLOTCHARACTER=",P$[1]
101: ent "PLOTDENSITY =",U
102: wtb 7,27,46,P$[1],int(U/64),int(U),0
103: wtb 7,27,65,int(X[A,1]/64),int(X[A,1]),int(Y[A,1]/64),int(Y[A,1])
104: for B=2 to F
105: wtb 7,27,97,int(X[A,B]/64),int(X[A,B]),int(Y[A,B]/64),int(Y[A,B])
106: next B
107: fxd 0;fmt 3,8x,c;wrt 16.3,P$[1];prt " PD",U;prt " P#",A;spc 2
108: next A
109: ent "MIN. Y LABEL",r16;ent "MAX. Y LABEL",r17;ent "Y LABEL INCREMENT",r18
110: if X#300 or Y#450;gsb "XY"
111: fmt ,f7.1,c;37.8r14r16→L;r16→K
112: if r3>0;L-37.8r3r14→L
113: wtb 7,27,65,int(-(104-P)/64),int(-(104-P)),int(L/64),int(L)
114: wrt 7,K," -";K+r18→K;L+37.8r14r18→L
115: if K<=r17;jmp -2
116: ent "MIN X LABEL",r16;ent "MAX X LABEL",r17;ent "X LABEL INCREMENT",r18
117: fmt ,f5.2;47.2r13r16→L;r16→K
118: if r1>0;L-47.2r1r13→L
119: wtb 7,27,65,int(L/64),int(L),int(R/64),int(R);wrt 7,"|"
120: wtb 7,27,65,int((L-24)/64),int(L-24),int(-(20-R)/64),int(-(20-R))
*11901
```

```
121: wrt 7,K;K+r18→K;L+47.2r13r18→L
122: if K<=r17;jmp -3
123: wtb 7,27,65,int(P/64),int(P),int((R-50)/64),int(R-50)
124: dim C$[1,66];ent "TITLE",C$[1]
125: fmt ,c;wrt 7,C$[1]
126: ret
127: "XY":
128: wtb 7,27,65,int(P/64),int(P),int(Q/64),int(Q)
129: wtb 7,27,46,"|",int(10/64),int(10),0
130: wtb 7,27,97,int(P/64),int(P),int(R/64),int(R)
131: wtb 7,27,46,char(95),int(10/64),int(10),9
132: wtb 7,27,97,int(O/64),int(O),int(R/64),int(R)
133: ret
134: "PMIN":
135: prt " MIN Y",r3;prt " MAX Y",r2;prt " MIN X",r1;prt " MAX X",r0;spc 2
136: ret
137: "VertL":
138: ent "NAME OF Y AXIS",N$[3]
139: wtb 7,27,65,int((P-110)/64),int(P-110),int((Q-150)/64),int(Q-150)
140: wtb 7,27,77;fmt x,c
141: for A=1 to 20
142: wrt 7,N$[3,A,A]
143: next A
144: ret
*11935
```

```
0: % "ANGULAR RANGE OF MOTION"
1: wtb 7,10,10,10,10,10,10
2: fmt 1,15x,f8.3,4f12.0;sfg 14
3: fmt 2,15x,c8,4c12,/,/;fmt 3,15x,c,/,/,/
4: ent "FILE ?????",Q
5: dim A[20,28],B[20,28],D[27],S$[100],Y[4,20],X[4,20],I[1,20]
6: trk 1
7: ldf Q,A[*],B[*],D[*]
8: trk 0
9: ent "RIGHT FOOT ? [1=Yes]",Q
10: if Q=1;sfg 1;9→S;jmp 2
11: 12→S;sfg 2
12: ent "COMMENT ???",S$;wrt 7.3,S$;wrt 7.2,"t","T>THIGH","LEG>","T","F<LL"
13: 0→T→X[1,1]→X[2,1]→X[3,1]→X[4,1]
14: for H=1 to D[27]
15: √((A[H,S+1]-B[H,S+1])^2+(A[H,S+15]-B[H,S+15])^2)→M
16: √((A[H,S+2]-B[H,S+2])^2+(A[H,S+16]-B[H,S+16])^2)→N
17: B[H,S+15]-A[H,S+16]+B[H,S+16]→B[H,S+16]
18: B[H,S+1]-A[H,S+2]+B[H,S+2]→B[H,S+2]
19: √((A[H,S+1]-B[H,S+2])^2+(A[H,S+15]-B[H,S+16])^2)→Q
20: acs((M^2+N^2-Q^2)/2MN)→r13→Y[4,H]
21: atn((B[H,16]-A[H,16])/(B[H,2]-A[H,2]))→r10
22: if r10<0;180+r10→r10
23: √((A[H,2]-B[H,2])^2+(A[H,16]-B[H,16])^2)→M
24: √((B[H,2]-B[H,S])^2+(B[H,16]-B[H,S+14])^2)→N
25: √((A[H,2]-B[H,S])^2+(A[H,16]-B[H,S+14])^2)→Q
26: acs((M^2+N^2-Q^2)/2MN)→r0→Y[1,H]
27: √((A[H,S]-B[H,S])^2+(A[H,S+14]-B[H,S+14])^2)→M
28: √((B[H,S]-B[H,S+1])^2+(B[H,S+14]-B[H,S+15])^2)→N
29: √((A[H,S]-B[H,S+1])^2+(A[H,S+14]-B[H,S+15])^2)→Q
30: acs((M^2+N^2-Q^2)/2MN)→r1→Y[2,H]
31: r10→Y[3,H];wrt 7.1,T,r0,r1,r10,r13
32: T+D[H+1]→T
33: next H
34: wtb 7,12;4→P→r10;20→Q→F
35: 0→X
36: for S=2 to 17
37: X+D[S]→X
38: next S
39: 0→Y
40: for H=1 to 20
41: Y+D[H+1]→Y;Y-X→X[1,H]→X[2,H]→X[3,H]→X[4,H]
42: next H
43: dim O$[1],N$[2,20]
44: "CONTACT"→N$[1];"TIME (s.)"→N$[2]
45: fxd 2;gsb "PLOT"
46: gsb "VertL"
47: end
48: "PLOT":
49: max(X[*])→r0;min(X[*])→r1;max(Y[*])→r2;min(Y[*])→r3
50: gsb "PMIN"
51: ent "MIN Y",r3;ent "MAX Y",r2;ent "MAX X",r0;ent "MIN X",r1
52: gsb "PMIN"
53: if r1<0 and r0>0;r0+abs(r1)→r5
54: if r1>0;r0-r1→r5
55: if r1=0;r0→r5;300→X
56: if r3<0 and r2>0;r2+abs(r3)→r6
57: if r3>0;r2-r3→r6
58: if r3=0;r2→r6;450→Y
59: 17→r11;14→r12
60: 47.2r11→r11;37.8r12→r12;r11/47.2r5→r13;r12/37.8r6→r14
*478
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61: if r1<0;300+abs(47.2r1r13)→X
62: if r3<0;450+abs(37.8r3r14)→Y
63: if r1>=0;300→X
64: if r3>=0;450→Y
65: wtb 7,27,79,int(X/64),int(X),int(Y/64),int(Y)
66: r0r13*47.2→O;r1r13*47.2→P;r2r14*37.8→Q;r3r14*37.8→R
67: if r1>=0;0→P;O-47.2r1r13→O
68: if r3>=0;0→R;Q-37.8r3r14→Q
69: wtb 7,27,46,"|",int(10/64),int(10),0
70: wtb 7,27,65,int(0/64),int(0),int(Q/64),int(Q);if flg1;cfg 1;jmp 2
71: wtb 7,27,10,8,8,8,8;wrt 7,N$[1];sfg 1;jmp -1
72: wtb 7,27,97,int(0/64),int(0),int(R/64),int(R)
73: wtb 7,27,46,char(95),int(10/64),int(10),9
74: wtb 7,27,65,int(P/64),int(P),int(0/64),int(0)
75: wtb 7,27,97,int(O/64),int(O),int(0/64),int(0);wrt 7,"  ",N$[2]
76: for A=1 to r10
77: for B=1 to F
78: Y[A,B]37.8r14→Y[A,B]
79: if r3>0;Y[A,B]-37.8r3r14→Y[A,B]
80: X[A,B]47.2r13→X[A,B]
81: if r1>0;X[A,B]-47.2r1r13→X[A,B]
82: next B
83: next A
84: for A=1 to r10
85: ent "NEXT POINT TO PLOT= [0=STOP]",A
86: if A=0 or A>r10;gto 55
87: ent "PLOTCHARACTER=",O$[1]
88: ent "PLOTDENSITY =",U
89: wtb 7,27,46,O$[1],int(U/64),int(U),0
90: wtb 7,27,65,int(X[A,1]/64),int(X[A,1]),int(Y[A,1]/64),int(Y[A,1])
91: for B=2 to F
92: wtb 7,27,97,int(X[A,B]/64),int(X[A,B]),int(Y[A,B]/64),int(Y[A,B])
93: next B
94: fxd 0;fmt 3,8x,c;wrt 16.3,O$[1];prt " PD",U;prt " P#",A;spc 2
95: next A
96: ent "MIN. Y LABEL",r16;ent "MAX. Y LABEL",r17;ent "Y LABEL INCREMENT",r18
97: if X#300 or Y#450;gsb "XY"
98: fmt ,f6.0,c;37.8r14r16→L;r16→K
99: if r3>0;L-37.8r3r14→L
100: wtb 7,27,65,int(-(104-P)/64),int(-(104-P)),int(L/64),int(L)
101: wrt 7,K," -";K+r18→K;L+37.8r14r18→L
102: if K<=r17;jmp -2
103: ent "MIN X LABEL",r16;ent "MAX X LABEL",r17;ent "X LABEL INCREMENT",r18
104: fmt ,f5.2;47.2r13r16→L;r16→K
105: if r1>0;L-47.2r1r13→L
106: wtb 7,27,65,int(L/64),int(L),int(R/64),int(R);wrt 7,"|"
107: wtb 7,27,65,int((L-24)/64),int(L-24),int(-(20-R)/64),int(-(20-R))
108: wrt 7,K;K+r18→K;L+47.2r13r18→L
109: if K<=r17;jmp -3
110: wtb 7,27,65,int(P/64),int(P),int((R-50)/64),int(R-50)
111: dim C$[1,66];1→N;ent "TITLE",C$[N]
112: fmt ,c;wrt 7,C$[N]
113: ret
114: "XY":
115: wtb 7,27,65,int(P/64),int(P),int(Q/64),int(Q)
116: wtb 7,27,46,"|",int(10/64),int(10),0
117: wtb 7,27,97,int(P/64),int(P),int(R/64),int(R)
118: wtb 7,27,46,char(95),int(10/64),int(10),9
119: wtb 7,27,97,int(O/64),int(O),int(R/64),int(R)
120: ret
*31001
```

```
121: "PMIN":
122: prt " MIN Y",r3;prt " MAX Y",r2;prt " MIN X",r1;prt " MAX X",r0;spc
123: ret
124: "VertL":
125: dim K$[22];ent "NAME OF Y AXIS",K$
126: wtb 7,27,65,int((P-110)/64),int(P-110),int((Q-150)/64),int(Q-150)
127: wtb 7,27,77;fmt x,c
128: for A=1 to 22
129: wrt 7,K$[A,A]
130: next A
131: ret
*27919
```

```
0: % "EMG % FOR LOWER LIMB MUSCLES"
1: % E.M.G.PROGRAMFOR(-3-)MUSCLE
2: ent "TIME IN cs",r0;r0→r80
3: dim X[3,114],T[r0],A[r0],Y[3,114],R[7]
4: dsp "Set start point as origin";wait 1000;beep
5: dsp "Digitize end point";red 4,W,E;beep
6: dsp "digitize 6 p. of inactive line";wait 1500;beep
7: for A=1 to 6
8: dsp "digi point #",A;red 4,X,R[A]
9: next A
10: 0→Q
11: for A=1 to 6
12: Q+R[A]→Q;next A
13: Q/6→R[7]
14: √(W^2+E^2)→r1;r1/r0→r2
15: dsp "start digitizing with blue ";beep;wait 1500;beep
16: dsp "NOW MOVE SLOWLY I´M DIGITIZING";1→A
17: if A-1>=r0;gto 21
18: red 4,X,Y;X→X[1,A];X[1,A]/A→E;wait 50
19: if E<r2;jmp -1
20: if E>=r2;Y→T[A];A+1→A;jmp -3
21: for A=1 to r0
22: T[A]-R[7]→A[A]
23: if A[A]<0;0→A[A]
24: next A
25: for A=1 to r0
26: 100A[A]/max(A[*])→Y[1,A]
27: next A
28: for E=1 to r0
29: 0→A[E]
30: next E
31: 3→P→r10;r0→Q→F
32: ent "WHERE THE IMPACT ? ",r50;-r50→r51
33: for H=1 to F
34: H/100+r51/100→X[1,H]
35: next H
36: ent "RECORD DATA ? (0=NO)",r70;if r70=0;jmp 4
37: ent "FILE TO RECORD DATA ?",r60;ent "TRACK #",r61
38: trk r61;rcf 60,X[*],Y[*]
39: trk 0;prt " FILE ",r60;prt "##  ",r0
40: wait 5000;dim O$[1],N$[2,20];beep;wait 2000;beep
41: "CONTACT"→N$[1];"TIME (s.)"→N$[2]
42: fxd 2;gsb "PLOT"
43: gsb "VertL"
44: gsb "PRINT"
45: end
46: "PLOT":
47: max(X[*])→r0;min(X[*])→r1;max(Y[*])→r2;min(Y[*])→r3
48: gsb "PMIN"
49: -10→r3;100→r2;ent "MAX X",r0;ent "MIN X",r1
50: gsb "PMIN"
51: if r1<0 and r0>0;r0+abs(r1)→r5
52: if r1>0;r0-r1→r5
53: if r1=0;r0→r5;300→X
54: if r3<0 and r2>0;r2+abs(r3)→r6
55: if r3>0;r2-r3→r6
56: if r3=0;r2→r6;450→Y
57: 17→r11;3→r12
58: 47.2r11→r11;37.8r12→r12;r11/47.2r5→r13
59: r12/37.8r6→r14
60: if r1<0;300+abs(47.2r1r13)→X
*7204
```

```
61: if r3<0;450+abs(37.8r3r14)→Y
62: if r1>=0;300→X
63: if r3>=0;450→Y
64: wtb 7,27,79,int(X/64),int(X),int(Y/64),int(Y)
65: r0r13*47.2→O;r1r13*47.2→P;r2r14*37.8→Q;r3r14*37.8→R
66: if r1>=0;0→P;O-47.2r1r13→O
67: if r3>=0;0→R;Q-37.8r3r14→Q
68: wtb 7,27,46,"|",int(10/64),int(10),0
69: wtb 7,27,65,int(O/64),int(O),int(Q/64),int(Q);if flg1;cfg 1;jmp 2
70: wtb 7,27,10,8,8,8,8;wrt 7,N$[1];sfg 1;jmp -1
71: wtb 7,27,97,int(O/64),int(O),int(R/64),int(R)
72: wtb 7,27,46,char(95),int(10/64),int(10),9
73: wtb 7,27,65,int(P/64),int(P),int(0/64),int(0)
74: wtb 7,27,97,int(O/64),int(O),int(0/64),int(0)
75: for B=1 to F
76: Y[1,B]37.8r14→Y[1,B]
77: if r3>0;Y[1,B]-37.8r3r14→Y[1,B]
78: X[1,B]47.2r13→X[1,B]
79: if r1>0;X[1,B]-47.2r1r13→X[1,B]
80: next B
81: for A=1 to r10
82: ent "NEXT POINT TO PLOT= [0=STOP]",A
83: if A=0 or A>r10;gto 93
84: ent "PLOTCHARACTER=",O$[1]
85: ent "PLOTDENSITY =",U
86: wtb 7,27,46,O$[1],int(U/64),int(U),0
87: wtb 7,27,65,int(X[1,1]/64),int(X[1,1]),int(Y[1,1]/64),int(Y[1,1])
88: for B=2 to F
89: wtb 7,27,97,int(X[1,B]/64),int(X[1,B]),int(Y[1,B]/64),int(Y[1,B])
90: next B
91: fxd 0;fmt 3,8x,c;wrt 16.3,O$[1];prt " PD",U;prt " P#",A;spc 2
92: next A
93: 0→r16;100→r17;25→r18
94: if X#300 or Y#450;gsb "XY"
95: fmt ,f6.0,c;37.8r14r16→L;r16→K
96: if r3>0;L-37.8r3r14→L
97: wtb 7,27,65,int(-(104-P)/64),int(-(104-P)),int(L/64),int(L)
98: wrt 7,K," -";K+r18→K;L+37.8r14r18→L
99: if K<=r17;jmp -2
100: ent "MIN X LABEL",r16;ent "MAX X LABEL",r17;ent "X LABEL INCREMENT",r18
101: fmt ,f5.2;47.2r13r16→L;r16→K
102: if r1>0;L-47.2r1r13→L
103: wtb 7,27,65,int(L/64),int(L),int(R/64),int(R);wrt 7,"|"
104: wtb 7,27,65,int((L-24)/64),int(L-24),int(-(20-R)/64),int(-(20-R))
105: wrt 7,K;K+r18→K;L+47.2r13r18→L
106: if K<=r17;jmp -3
107: wtb 7,27,65,int(P/64),int(P),int((R-50)/64),int(R-50)
108: dim C$[1,66];1→N;ent "TITLE",C$[N]
109: fmt ,c;wrt 7,C$[N]
110: ret
111: "XY":fmt x,c
112: wtb 7,27,65,int(P/64),int(P),int(Q/64),int(Q)
113: wtb 7,27,46,"|",int(10/64),int(10),0
114: wtb 7,27,97,int(P/64),int(P),int(R/64),int(R)
115: wtb 7,27,46,char(95),int(10/64),int(10),9
116: wtb 7,27,97,int(O/64),int(O),int(R/64),int(R);wrt 7,N$[2]
117: ret
118: "PMIN":
119: prt " MIN Y",r3;prt " MAX Y",r2;prt " MIN X",r1;prt " MAX X",r0;spc
120: ret
*21035
```

```
121: "VertL":
122: dim K$[5];"% EMG"→K$
123: wtb 7,27,65,int((P-100)/64),int(P-100),int((Q-10)/64),int(Q-10)
124: wtb 7,27,77;fmt x,c
125: for A=1 to 5
126: wrt 7,K$[A,A]
127: next A
128: ret
129: "PRINT":wtb 7,12
130: fmt 1,2x,58"*",/;fmt 2,10x,c,/;fmt 3,c8,c8,c13,c8,c13,c8
131: fmt 4,4x,f3.0,f8.0,f14.0,f7.0;fmt 5,f49.0,f8.0
132: wrt 7.1;dim T$[30];ent "TITLE",T$;wrt 7.2,T$
133: wrt 7.1;wrt 7.3,"TIME","%EMG","TIME","%EMG","TIME","%EMG"
134: for W=1 to r80
135: if Y[1,W]>=100;100→Y[1,W]
136: next W
137: for A=1 to 38
138: wrt 7.4,A,Y[1,A],A+38,Y[1,A+38];wtb 7,27,10
139: if A>=r80;jmp 2
140: wrt 7.5,A+76,Y[1,A+76]
141: next A
142: wtb 7,12;wtb 7,27,69
143: ret
*2135
```